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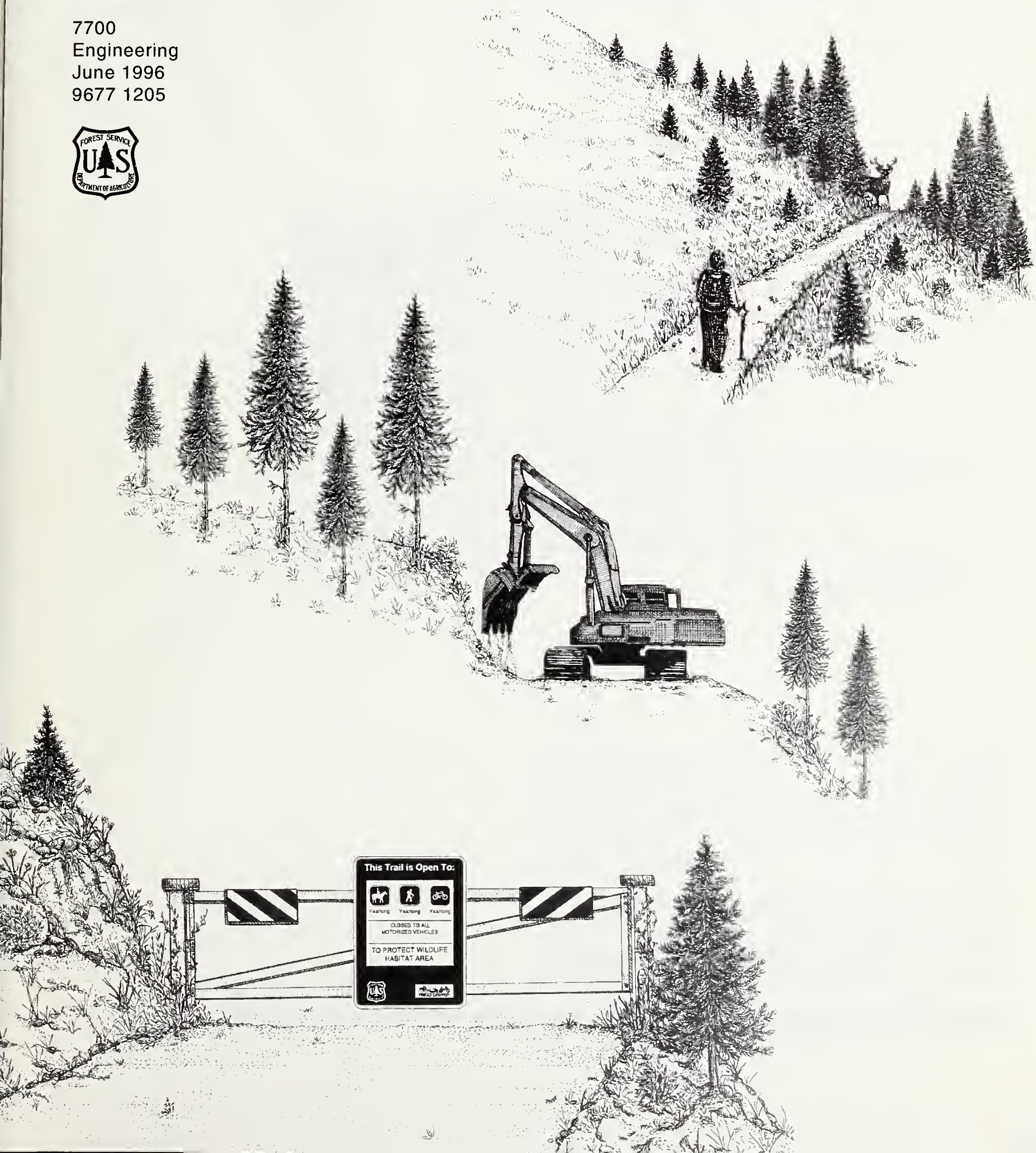
A Guide For

Road Closure And Obliteration In The Forest Service



Cover illustration by Debra Lynn Lovitt

Excavator performing a partial recontour—converting an unneeded road prism into a trail.

A Guide for

Road Closure and Obliteration in the Forest Service

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PREFACE

Prior to discussing the road closure and obliteration process, boundaries defining discussion scope must be established. This guide spans the process from field reconnaissance through effectiveness monitoring and is founded on resource specialist input. Roads to be treated by the process have already been placed in an unneeded category, based on transportation system analysis and NEPA scoping. If unneeded for a specific amount of time, the road is in "closure" status; if never needed again, the road will undergo natural or mechanical "obliteration," given effective access control. In either case, site- and condition-specific treatments are in order. Boundaries contain the road corridor, adjacent areas, a consideration of watershed conditions, and the efforts of resource specialists to meet line officer objectives. The guide was conceived with low-volume roads in mind.

Restricted- and unrestricted-use roads are not within the scope of this guide, nor are cultural or biological resources, budgetary constraints, decision making, or risk assessment.

The next few years will no doubt see many leaps forward in the development of treatments and techniques used in road closure and obliteration. It is hoped this guide will aid in field reconnaissance, prioritizing work, optimizing use of funds, and maximizing benefits to the ground.

The vision is of road prisms successfully transformed into functioning components of healthy ecosystems. Once vegetation was eradicated and soil disturbed, slopes steepened, water concentrated, and drainages from the road integrated into the natural stream network, with undesirable repercussions occurring to the environment. Now, provision is made for access control, restored hydrology, reduced erosion and sedimentation, increased stability, and revegetation. Targets and treatments are tailored to closure or obliteration status and ground conditions and needs. Consideration is made of watershed conditions in addition to the road corridor. Effectiveness monitoring guides project planning for future efforts.

Successes will be achieved and much will be learned as Forest Service field units accomplish project work. Mistakes will be made and failures will also undoubtedly occur. These need to be expected as they are integral in defining ultimate success.

This guide is mainly the product of the efforts of employees of the USDA Forest Service. It is my sincerest hope that this compilation of information measures up to their hard work, dedication, innovation, and respect for our natural resources and heritage.

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DEFINITIONS

***Note:** The definitions contained herein are specific to the needs of this report.*

Abandonment: No-action treatment on a road or road segment, made possible by a lack of needs in priority areas (see "priority" and "systems approach").

Closure: Storage of a road for future use, with treatments to the road corridor and surroundings based on site conditions and closure duration.

Cumulative Effects: Accumulating results of past and present activities; a produced effect or change, usually undesirable, amassed due to over-utilization of resources and the access thereof.

Cut: Excavation of material to provide travelway width or to generate material for fills, landings, or other uses.

Decompaction: Compaction reduction; ripping; to loosen or reduce the density of soil, road subgrade, or surfacing material.

Embankment: Fill to provide travelway width, a landing, or the waste of excess excavation, made by building up material; side cast, through-fill, turnpike, channel crossing, or channel encroaching. Hydrological definition: earth-filled dam.

Gully: Intermittently flowing, relatively recent drainage fixture on the landscape formed by concentrated surface flow, often traced to removal of vegetative cover and soil compaction through some human activity.

Hydrograph: Graph depicting discharge of water versus time for a watershed, including surface, subsurface, and base flows.

Hydrology: The water of the earth and air; its flow, distribution, characteristics, and actions.

Obliterate: To unbuild, decommission, deactivate, or dismantle a road; the denial of use, elimination of travelway functionality, and removal of the road from the forest development road system; return of the road corridor to resource production by natural or designed means.

Planting pocket: A treatment to shape topography to hold moisture and provide protection for vegetation.

Priority: One of a group of separate but interrelated areas of need, which, when altered, can lead to enhancements or undesirable repercussions among the others. Five priorities are identified and discussed in this guide:

Access: travelways for vehicular use; ground transportation system making possible the ability to utilize resources; for purposes of this guide, to be discouraged or eliminated.

Drainage: the flow of water; a topographical feature created and shaped by the flow of water.

Erosion: the wearing away of soil or rock by water or wind, accompanied by downstream sedimentation or deposition.

Stability: permanence; resistance to sudden change or deterioration relative to physical landscape.

Revegetation: encouraging, establishing, or trending towards a previous or desired vegetation regime and soil cover condition.

Prism: (roadway) top of the cut to the toe of the fill on the road template cross-section for a road segment; change in topography due to the construction, maintenance, or use of a travelway and associated surfaces of a roadway. Hydrological definition: cross-slope gully that concentrates and channels water.

Prism Treatment Prescriptions: A range of road prism treatments designed to modify, reduce, or eliminate road-induced changes to natural topography while economically optimizing earthwork. The range is as follows:

Slope break rounding: A rounding of slope breaks at the top and toe of cut and fill slopes to reduce raveling and erosion and facilitate revegetation.

Self-balancing outslope: To fill ditches, remove berms, and outslope the travelway without significant haul or push of material.

Outsloping cut or fill: Similar to the self-balancing outslope but generating or consuming material, respectively.

Partial re-contour: To replace cut or remove fill material, or both, while leaving a flat or sloped section of the travelway intact, usually for use as a trail.

Full re-contour: To restore topography; return of areas with road prisms and other modifications to the natural contour—as well as possible—to previous shape or form.

Reconnaissance: Examination or survey of a watershed for the express purpose of planning treatments for closure or obliteration of road prisms and treatments to or alleviation of other disturbed areas; reconnoiter.

Resource Specialist: Person trained, experienced, and devoted to a subject in the natural sciences relating to watershed health and forest resources.

Restoration: Reestablish, bring back to health or vigor, put or give back, restitution.

Restricted Access: Road with specific use requirements, outside the scope of this report.

Road (Prism): for purposes of this report, an unneeded travelway or prism on the landscape exhibiting characteristics and interactions with the surrounding environment that make treatments desirable.

Road Density: The sum of road prism lengths in a watershed divided by watershed area.

Silt Trap: A treatment to abate sedimentation and retain surface flows from disturbed areas; a depression or shaped topography that catches water for wildlife, vegetation, soil preservation, and storm flow detention and de-synchronization; a constructed wetland that eventually fills in with sediment.

Subsoiling: A treatment to loosen soil, usually by deep shattering without inversion and with a minimum of mixing.

Systems Approach: A system for formulating the problem and implementing its solution; broad-based systematic approach to interdisciplinary problems; a process for road closure and obliteration projects based on priorities, considering each of the following:

Planning: defining priorities, trends, and targets; conducting reconnaissance; preparing for action, defining purpose or scope.

Trend: course or tendency in natural processes relating to watershed, hydrological, or vegetative health.

Target: desired trend or end condition in natural processes.

Treatment: what is done on the ground in striving towards a target or targets.

Technique: method or procedure for accomplishing a treatment.

Monitoring: studying results to guide future efforts; measuring effectiveness; comparing accomplishments to targets.

Temporary Road: A road constructed for a timber sale, fire suppression, or other short term access needs, not necessary for resource management, and not intended to remain part of the permanent forest development transportation system.

Unrestricted Access: An open road or travelway, outside the scope of this report.

Variable Source Area (VSA): Stream networks and wetlands that expand and contract with precipitation and changes in soil moisture, thus affecting runoff response.

INTRODUCTION

This guide is a compilation of information on road closure and obliteration and related watershed restoration work as an aid to resource specialists, engineers, and the interdisciplinary (ID) team process. It is based largely on submissions from Forest Service field units to the Road Closure and Obliteration Project (Road C & O) at the San Dimas Technology and Development Center (SDTDC).

A discussion of terminology is warranted: road "closure" denotes storage for future use; the road remains on the forest development transportation system and the closure is accomplished by natural or designed blockage or by regulation. Periodic inspection and maintenance may be required. Closed roads sometimes receive treatments as discussed in the guide based on site conditions and duration of closure. Road "obliteration" is the denial of use, elimination of travelway functionality, and return of the corridor to resource production; its accomplishment can be by natural or designed means. Periodic monitoring may be required. Unrestricted and restricted use roads are outside the scope of the guide.

The guide presents a systems-based process for C & O projects. The principles and priorities of C & O are introduced, as are targets and treatments. Techniques for access control, low volume road recontouring, and channel crossing restoration are discussed, as are techniques for altering peak flows, gully control, and increasing stability with off-site materials and products. Background information on road and land modification effects on natural hydrology, tips on locating temporary roads to facilitate their obliteration, and a basin study checklist for slope-stability investigations appear in appendices.

Background

Roads exist to provide access and allow utilization of land and resources. Many forested watersheds exhibit accumulated adverse hydrological and environmental effects from past resource utilization and road building. Road C & O and related watershed restoration work are steps in environmental healing and initiating positive trending in natural processes; many resource specialists consider this work to be a critical component of ecosystem management.

Successfully planning, implementing, and monitoring C & O projects depends on a knowledge of the mechanics of road and land modification effects on hydrology. Equally important is the ability to identify adverse environmental effects—and the potential for effects—in the field. Appendix A includes a brief discourse on road and land modification effects.

A SYSTEMS APPROACH FOR ROAD CLOSURE AND OBLITERATION PROJECTS

The systems approach is particularly useful in attacking complex problems affected by many factors. A problem model is created that corresponds as closely as possible to reality. The system discourages, initially, presenting a specific problem definition or adoption of a particular model. Instead, the problem environment is emphasized in broad terms, reflecting the wide variety of complex factors, relationships, and conflicts implicit in the problem context. A broad overview of the systems approach (ref. 33) plus steps and milestones applicable to the interdisciplinary team process is as follows:

STEPS	MILESTONES
	Needs Recognized
Problem Definition	
	Problem Understanding Formulated
Plan Approach	
	Problem Formulated
Allocate Resources	
	Problem Solution Effort Defined
Model and Analyze	
	Analysis Procedures Defined
Design and Evaluate Alternatives	
	Solution Proposals Available
Select Preferred Alternative	
	Solution Attained

The systems approach is initiated with *Problem Definition* in recognition of demonstrated need. The *Plan Approach* step includes establishment of targets and considers the nature of alternatives and how effectiveness is to be monitored. *Allocate Resources* is the examination of the time, person-power, and capital required to achieve a solution. Resource constraints may affect the approach taken or force a reconsideration of problem scope. To this point, the focus is on the conceptual attack of the problem.

The next step, *Model and Analyze*, reflects detailed technical analysis—based on site-specific information—and forms the basis for the design and evaluation of alternatives. During the *Design and Evaluate* step, each alternative is subjected to a thorough analysis based on cost, benefit, and consequence. Alternatives are ranked and viewed relative to the sensitivity of the solution to changes in design parameters or conditions.

Project-specific gates (similar to those in the timber sale process) are a product of the systems approach, as is the preferred alternative; *Select Preferred Alternate* is the responsibility of the appropriate line officer. A gate for monitoring effectiveness provides a feedback loop for future efforts. Optimizing allocation of resources for C & O constitutes a challenge to land managers, as does determination of natural, background, or desirable conditions and trends. The effective closure and obliteration project:

- Addresses priorities of access, drainage, erosion, stability, and revegetation
- Identifies needed treatments based on targets and desirable trends
- Relies on resource specialist planning, design, and monitoring
- Is founded on accurate and complete inventories and land management plans
- Is sufficiently funded, affords ample lead time, and involves the public
- Is systems-process oriented and contains well-defined gates
- Is in compliance with environmental law and regulation.

PRINCIPLES OF ROAD CLOSURE AND OBLITERATION

- Plan and implement projects according to a systems process with identified priorities, clearly defined, visualized, and attainable targets, site-specific treatments, and monitoring of completed work.
- Divide a road to be closed or obliterated into segments, each with site-specific targets that address priorities of access, drainage, erosion, stability, and revegetation.
- Evaluate the entire watershed; treat root problems rather than symptoms, avoid partial or piecemeal fixes, and minimize disturbances within the context of project targets.
- Work in concert with and design for positive trending in natural processes; duplicate natural land forms and utilize naturally occurring materials whenever possible.
- Exploit every opportunity to break up undesirable water concentrations and enhance desirable in-situ moisture conservation; create opportunities when none occur naturally.
- Convert high risk or damage potential problems to moderate or low risk situations; sustain or maintain low risk situations.
- Build stability and self maintenance into closed and obliterated roads.
- Realize short term impacts may occur while providing for long term benefits. Ensure project work can survive the short term.
- Provide for short and long term revegetation of road corridors and disturbed areas.
- Provide for erosion and sedimentation control during and after project work.
- Effectiveness monitoring and well documented results of previous efforts are invaluable tools in planning future projects.

PRIORITIES FOR ROAD CLOSURE AND OBLITERATION

For purposes of this report, a "priority" is a separate but interrelated area of need which, when altered, can lead to enhancements in or undesirable repercussions among other priorities. Conditions in one or more priority areas may justify treatments to a road corridor and its surroundings. Priorities include access, drainage, erosion, stability, and revegetation. Aesthetics may be an additional priority requiring consideration, with related targets addressed by appropriate treatments discussed herein.

C & O projects are undertaken to address priorities identified by resource specialists (ref. 6). Priorities become apparent during large scale and watershed scale analysis, as well as during field reconnaissance, form the basis for identification of desirable trends, and lead to targets, which are attained by site-specific treatments.

Priorities must not be confused with treatments. For example, "decompaction" may be considered a priority on a certain road being obliterated, but the project is undertaken and decompaction performed to address related access, drainage, erosion, stability, or revegetation concerns.

Access

Access as a priority exists due to the function of the transportation system—to make possible the utilization of resources. C & O is not possible when access is uncontrolled. Access and travel management coupled with land management planning identifies use requirements for existing roads as well as new access needs; other roads become candidates for closure or obliteration. Access decisions must be based on complete, accurate road inventories and forest land management plans. Factors dictating road location may facilitate optimizing an environmentally sensitive transportation plan that best addresses future needs. This optimization may result in the proposed obliteration—and relocation—of some road segments.

Drainage

Drainage is a priority due to the hydrologic definition of a low volume road prism: a cross-slope gully that concentrates and channels water. Peak flows increased by road building and other activities in the watershed should be treated during C & O work, as should any increased drainage density, efficiency, and networking, and the connectivity of prism-induced drainages to the natural system.

Watershed shape affects the rapidity with which surface and subsurface flows concentrate; all else equal, round shapes have higher peak discharges. A higher percentage of watershed area composed of lakes, wetlands, and reservoirs results in a flatter hydrograph as storm flows are detained and desynchronized and water is temporarily stored. Evaluate the entire watershed as a functioning unit.

C & O should be coupled with restoration of adjacent areas, considering infiltration, subsurface flow, base flow, translatory flow (flow by displacement), and the configuration of variable source areas (VSA's) that existed prior to road building and other activities. VSA's are stream networks and wetland areas that expand with increasing precipitation and soil moisture levels. They are integral to natural runoff patterns and response. The VSA concept credits two contributors with quick flow response, the first an expanding saturated-soil source for flow directly into the channel, and the second a rapid subsurface contribution from upslope areas due to flow by displacement in the soil (ref. 7).

In drainage restoration work consider site-specific characteristics and processes including the following:

- Climatic and environmental factors such as intensity, duration, and flashiness of storms, occurrence of rain-on-snow events, freeze-thaw cycles, snow accumulation in clear cuts and other clearings, and the critical antecedent (relative) moisture storage status of soils
- Natural hydrology and target conditions
- Soil organics, mineralogy, gradation, and depth
- Side slope morphology (concavity, convexity, or planarity), steepness, and length
- Geomorphology, vegetation, elevation, aspect, climate, and land use

- Location of roads in the watershed; proximity to drainage bottoms, riparian areas, and other disturbed areas.

Erosion

Erosion exists as a priority because most land disturbance and roading result in the acceleration of erosion and sedimentation: the detachment, transport, and subsequent deposition of soil particles. Landscape evolution is a series of states of balance between geological formation of uplands, erosional wearing away (ref. 42), and sedimentation. A main concern is the acceleration of erosion and consequent sedimentation of streams. Most erosional problems on forestlands are attributed to improper road and skid trail design, location, and layout (ref. 7). Roads and other land modifications result in a geometrical progression of erosion as protective vegetative and organic cover is removed, soil disturbance occurs, steepened slopes are introduced, water concentrates, gullies form, the site dries, and other damage to the fluvial system occurs. Avoiding erosion-susceptible situations and inappropriate land uses are the most economical and effective means to combat soil erosion and sedimentation downstream to maintain watershed productivity. Once soil is gone, gone also is the necessary medium for moisture, organics, nutrients, air, and plant roots.

Erosion types are listed in terms of increasing magnitude (ref. 10):

- Groundwater erosion is the movement of fine material underground due to subsurface flow.

- Raindrop impact erosion occurs as the force of the falling drop dislodges soil particles, making them available for transport. Splash moves some particles to plug pores in the soil surface, increasing surface layer density and decreasing porosity and infiltration, thus further increasing runoff and erosion potential—referred to as "surface sealing." Rain drop impact erosion is greatly increased as vegetation is removed, forest floor organics are disturbed, and mineral soils exposed.

- Sheet erosion is a direct result of raindrop impact erosion and is relatively uniform over a smooth surface. Sheet flow rarely occurs on undisturbed forest soils due to protective cover, the presence of organics, and interconnected pore spaces within the upper soil strata.

- Rill erosion results when sheet erosion begins to cut into the surface; flow attains sufficient force to detach particles for transport in suspension or by rolling.

- Gully erosion is the continuance of rill erosion and is greatly intensified by water concentration. The capture, storage, and safe release of moisture is paramount in preventing gully erosion.

- Fluvial erosion is the continuance of gully erosion and is characterized by down cutting in certain areas and sedimentation in others, as eroded material from highlands becomes deposition in lower areas. Sediment delivery contributes to aggraded and widened channels, reduced pools, braided streams, and shallower flows. Fish habitat and water quality suffer as channel erosion and sedimentation are elevated.

Stability

Like erosion, stability is a priority because land disturbance and roading tend to exacerbate stability problems. Slope stability studies in the USDA Forest Service have been conducted successfully in accordance with a three-level concept (ref. 41). The Slope Stability Reference Guide for National Forests in the United States discusses the forest planning process, geomorphology, channel processes and sediment budgets, climatology, soil and rock mechanics, hydro-geology, exploration and testing methods, and risk analysis as applicable to slope stability.

The following are among the characteristics relating to slope stability investigation identified during field reconnaissance:

- Physical change in the landscape from road construction and other activities in the forest and due to cumulative effects. Road fills increase steepness and place added burdens on slopes, creating stability problems or elevating moderate risks to higher risks. "Risk" in the context used here is a function of probability and consequence. Road cuts undermine upper slopes, increasing the probability of soil movement and mass failure.

- Road construction techniques, slash disposal techniques—such as burying it in road fills—the prevailing road standards of the era in which construction took place, and road location, grade, and density.

- Mass movement potential changes due to vegetation loss. Roots can increase shear strength, while transpiration removes soil moisture, which reduces the weight of the soil mass, increases internal friction, lowers pore water pressure, and reduces chemical weathering, all of which can increase stability.

- Soil moisture and saturation, ground water, and exfiltration.

- Geology:

  - Drainage and erodibility of soils, and the potential for mass failures

  - Slope length, gradient, and shape

  - Bedrock competency, composition and weathering

  - Strike and dip of strata: strata dipping in the direction of slope leads to lower stability and facilitates mass wasting

  - Mechanical and chemical decay versus stability of minerals

  - Topographical influences on climate, as topography controls the rate at which debris is removed from eroding terrain, which affects both chemical and mechanical weathering rates (ref. 42)

  - Steep v-shaped canyons lead to large cuts and fills in construction of channel crossings.

See Appendix C, a basin study checklist for slope stability investigations. This checklist is repeated verbatim from the Slope Stability Reference Guide (ref. 41).

Revegetation

Revegetation is paramount in healing disturbed areas. Vegetation can camouflage road junctions (ref. 46) and block access, roughen the ground surface, slow drainage, reduce erosion, increase infiltration and deposition, and enhance in-situ moisture conservation. It provides organic material, shade, and cover, helping reduce evaporation due to sun and wind. Plant roots can stabilize slopes, break up soil, increase shear strength, and increase porosity, further encouraging infiltration. Evapotranspiration can reduce soil moisture, resulting in more available storage for the next precipitation event. Heavily vegetated watersheds act as sponges (ref. 9) and clean the air. Revegetation places the land "back in production," for example, growing timber, and helps to rebuild top soils as organic matter and nutrients accumulate and are recycled and conserved. Main concerns include difficult conditions for revegetation and the introduction of noxious weeds and exotic varieties of plants.

As slopes are denuded of vegetation, drainage and erosion can increase, while stability may decrease. Timber harvest and overgrazing may increase water yield (ref. 12 & 27) due to reduced evapotranspiration, potentially increasing peak flows and erosive energy (ref. 48). This can result in less on-site moisture and reduced organics, further decreasing the likelihood of successful revegetation.

Taking a holistic approach in revegetation and hydrologic health will help establish and maintain vegetative cover and plant litter on eroding sites and adjacent areas where runoff originates. Treating the gully alone often is ineffective; installing permanent in-stream structures in rangeland riparian areas without changing vegetation management usually will be counterproductive over the long term (ref. 12).

TARGETS FOR ROAD CLOSURE AND OBLITERATION

Once project priorities are identified, targets may be visualized and defined. Environmentally-based targets are attainable by specific treatments and are met by initiating and nurturing positive trending in natural processes. Example targets are provided here to aid field reconnaissance and the *Plan Approach* step of the systems approach, and are categorized by priority:

Targets by Priority

PRIORITY: ACCESS

TARGET
Eliminate or discourage access. Reduce transportation system maintenance expenditures and optimize the transportation system and ATM (access and travel management). Increase environmental sensitivity and quality of wildlife and fish habitat. Return road corridors and other disturbed areas to resource production.

PRIORITY: DRAINAGE

TARGET
Enhance desirable in-situ moisture conservation; increase base flows, moisture available for vegetation and wildlife, quality of fish habitat, and groundwater recharge. Reduce undesirable water concentrations, peak flows, drainage density and efficiency, and other modifications to natural hydrology. Restore perennial flow. Eliminate potential for drainage structure failure and stream diversion. Provide for capture, storage, and safe release of moisture.

PRIORITY: EROSION

TARGET
Reduce soil and organics loss, embankment washout, sedimentation, turbidity, and damage to the fluvial system and fish habitat Reduce or eliminate erosion induced damage resulting in reductions to in-situ moisture conservation. Control eroded sediments so that they do not enter streams.

PRIORITY: STABILITY

TARGET
Reduce mass wasting, failures, slides, and slumps. Reduce instabilities to acceptable levels of risk. Preserve soil and soil integrity.

PRIORITY: REVEGETATION

TARGET
Establish or encourage specific vegetation regimes. Provide cover and organic matter to soil. Enhance in-situ moisture conservation, quality of wildlife and fish habitat, and break up compacted soil and water concentrations. Success in this area enhances positive trending in other priority areas.

PRIORITY: AESTHETICS

TARGET
Heal scars. Enhance visual qualities of road corridors and disturbed areas.

TREATMENTS AND TECHNIQUES FOR ROAD CLOSURE AND OBLITERATION

For purposes of this report, a "treatment" is WHAT you do to attain a target, while a "technique" is HOW you do it. C & O treatments and techniques play important roles in managing access, reducing maintenance expenditures for transportation systems, returning land to production, and optimizing healing trends in natural processes. Problems are identified during field reconnaissance; the road is subsequently divided into segments based on unique needs. Adjacent area conditions can also dictate segment breaks. On many roads placed in the obliteration category, mechanical means are needed only on certain segments. Other segments are inherently innocuous, stable, or revegetated to the extent that mechanical treatments are unneeded or might cause undue disturbance.

Treatments are based on closure or obliteration status and environmental issues, concerns, and opportunities, and are defined during the *Model and Analyze* step of the systems approach. They involve areas adjacent to the road corridor, optimize use of available resources, and maximize benefits to the environment. Once a treatment is identified, alternative techniques and detailed cost estimates for accomplishment may be considered during the *Design and Evaluate* step of the systems approach. Site-specific cost estimates are best prepared in accordance with Regional Cost Estimating Guides by experienced cost estimators familiar with local conditions, labor, equipment, materials, and construction practices.

Access Control

Treatments used to control access involve discouraging or eliminating vehicular use. Public meetings are conducted to inform, educate, and gain acceptance and support from the public on closure policies. Signing, documentation, turnarounds, and

developed trailheads (where applicable) aid public understanding of management policies.

On-site materials economically and effectively crafted into road blockages include rocks, logs, stumps, slash piles, tank-traps, water bars, and vegetation. Fences, posts, guardrails, gates, and concrete barriers are also used. Wood barriers reinforced with metal strips to deter chain-sawing can be made aesthetically pleasing (ref. 11). Camouflaging a closed road is enhanced by obliteration of the junction and initial stretch of road, rock and log placements, and vegetative plantings and transplantings (ref. 46).

Decompaction of travelway surfaces and drainage structure removal also discourages use. Road closure devices allow quick and easy access if required. Devices manufactured of steel perforated telescoping tubing and pipe, anchored in concrete and fitted with locks, object markers, and appropriate signing are available for single to double lane widths (ref. 20). Devices of 20 cm (8 inch) well casing and 5 cm (2 inch) pipe have also successfully been placed into service (ref. 43).

See Table 1 for a summary of access control treatments. Cost ranges are necessarily wide due to the national scope of this guide.

Table 1.—*Access control treatments*

Closure Type	Description	Purpose/Application	Cost
Blockage with On-Site Materials	Rock, logs, stumps, slash piles, posts, water bars, tank traps, decompaction	Discourage use, economical, dependent on-site and available material	\$50-\$500 plus move in
Vegetative Planting, Seeding	Trees, shrubs, cactus, and grass seeding, recycled paper mulch, chip and spread slash	Discourage use, camouflage road, speed revegetation and healing of site, provide browse and forage	\$100-\$1000 depending on conditions
Imported Material	Fences, gates, posts, guardrails, concrete barriers	Discourage use, lack of on-site material or inappropriate site for use of on-site materials	\$200-\$2000 depending on conditions
Pole Fences Wood Barriers	Onsite or imported poles, reinforce with metal strips to deter chain-sawing	Discourage use, can be dismantled for emergency access, aesthetically pleasing	\$500-\$5000 depending on conditions
Closure Devices	Materials used include metal telescoping tubing, pipe, and well casing. Available in single lane to double lane widths	Discourage use, allow quick, easy access, single or multiple locks, signing	\$500-\$5000
Obliteration	Re-contour road junction or entire road. Combine with other closure treatments. Removal of drainage structures, bridges, and associated embankments	Eliminate travelway, return corridor to resource production, reduce modifications to hydrology and aesthetics, camouflage road	\$2-\$5 per line meter of single lane, road plus structure removal

Treatments And Techniques By Priority

Most treatments afford benefits to more than one priority area. A road may effectively be "hydrologically obliterated" by removing and reshaping channel crossings, removing cross-drain culverts, removing or stabilizing unstable or potentially unstable fills, and replacing inslope and ditches with outslope. In this way, the road is made erosion and failure resistant while leaving most of the prism intact. The effort is made here to present treatments in the order of main priority emphasis. The successful C & O project depends on an evolution from visualized treatments to effective techniques implemented on the ground.

Abandoned roads usually revegetate, effectively closing and contributing to stabilization and natural obliteration over time, although road prisms apparently "healed over" may still undesirably affect the hydrology of a watershed (see Appendix A). Only roads not requiring treatments in priority areas should be abandoned, and roads with abandonment—"no action"—as the preferred alternative may still require access control.

Drainage

Cross drain culverts, major drainage structures, bridges, and associated embankments are sometimes removed on roads being closed, depending on length of closure and ground conditions, and are usually removed on roads being obliterated (ref. 6, 15, 28, 30). Removal prevents eventual structure failure due to plugging, piping, scour, undermining, or overtopping, helps restore natural drainage patterns, and alleviates modifications to channel hydraulics. Removing embankment material helps prevent diversion, washout, and instabilities, aids in restoring watershed function, and reduces channeling, erosion, and sedimentation. Removal can also discourage or eliminate access.

Some Forest Service field units report limited experimentation with leaving drainage structures in place coupled with partial embankment removals in low risk situations, i.e., flat road grades; deep, permeable soils; moderate side slopes and climatic conditions; and low potential for overland flow. In these cases, alternative drainage is provided; for example, a "low water crossing"— monitoring takes place, and it is realized that structures and embankments not removed may be inaccessible for maintenance or repair after road obliteration work is completed.

Replace cross drains with an appropriate number of water bars or cross ditches designed, located, and tailored to the site and road grade (ref. 47). Long term planning should consider that water bars ultimately erode or revegetate and sediment-in. One rule of thumb for native-surfaced roads is to install water bars at points of opportunity, spaced by approximately two meters in elevation. Thus, on a 10 percent road grade horizontal spacing is 20 meters. Water bar spacings used by the Maine Forest Service are as follows (ref. 30):

Road Grade	Water Bar Spacing	
(percent)	(meters)	(feet)
1-2	76	250
3-5	61-41	200-135
6-10	30-24	100-80
11-15	24-18	80-60
16-20	18-14	60-45
21+	12	40

Maximum water bar spacing used by the Siuslaw National Forest (ref. 47) in Region 6 are as follows:

Road Grade (percent)	Aggregate Surfaced with Vegetated/ Rocky Discharge Points		Native Surface or Barren Soil Discharge Points	
	(m)	(ft)	(m)	(ft)
1-3	165	540	30	100
4-6	82	270	24	80
7-9	55	180	21	70
10-12	43	140	18	60
13-15	34	110	15	50
16-18	27	90	12	40
19+	21	70	9	30*

*Consider using surface protection measures such as aggregate.

Water bar spacing should be adjusted for areas with steep side slopes, shallow soils, intense precipitation, high soil moisture, ground water, ex-filtration, or frequent surface flows. Water bars may be shaped to function as-or drain into-silt traps and wildlife drinkers. Rock-plating or placing slash or logs on water bar outflows and lead-out ditches encourages self maintenance, spreading of flows and infiltration, and minimizes erosion.

Restoring and reshaping drainages after drainage structure and embankment removal to as near natural condition as practicable allows meanders and tortuosity and encourages hydrologic stability, while restoring flood plains slows storm flows and dissipates runoff energy. Channel inspection or survey above and below the embankment facilitates determination of natural channel characteristics at the site. See the section entitled "A CHANNEL CROSSING RESTORATION TECHNIQUE."

All else being equal, shallower flows, rougher surfaces, and larger wetted perimeters reduce erosion potential. Check-dam, rock-plate, revegetate, and place large woody debris (see figure 1) on reshaped drainage bottoms and sides. Duplicate natural forms and use on-site materials when possible to slow stream velocity and transport of bed load, provide vertical drop into plunge pools, and add cover and complexity to fish habitat. Whole trees are well used as large woody debris in riparian zones, with larger and longer stems providing greater stability (ref. 16).

Figure 1.—*Large woody debris placed in reshaped drainage bottom.*

Subsoiling is a compaction reduction technique that loosens soil without inversion and with minimum mixing. Lifting action produces a wave that shatters dry soil, increasing porosity, reducing density, and increasing infiltration. See figure 2 for a detail of a tool bar-mounted subsoiling implement (ref. 22).

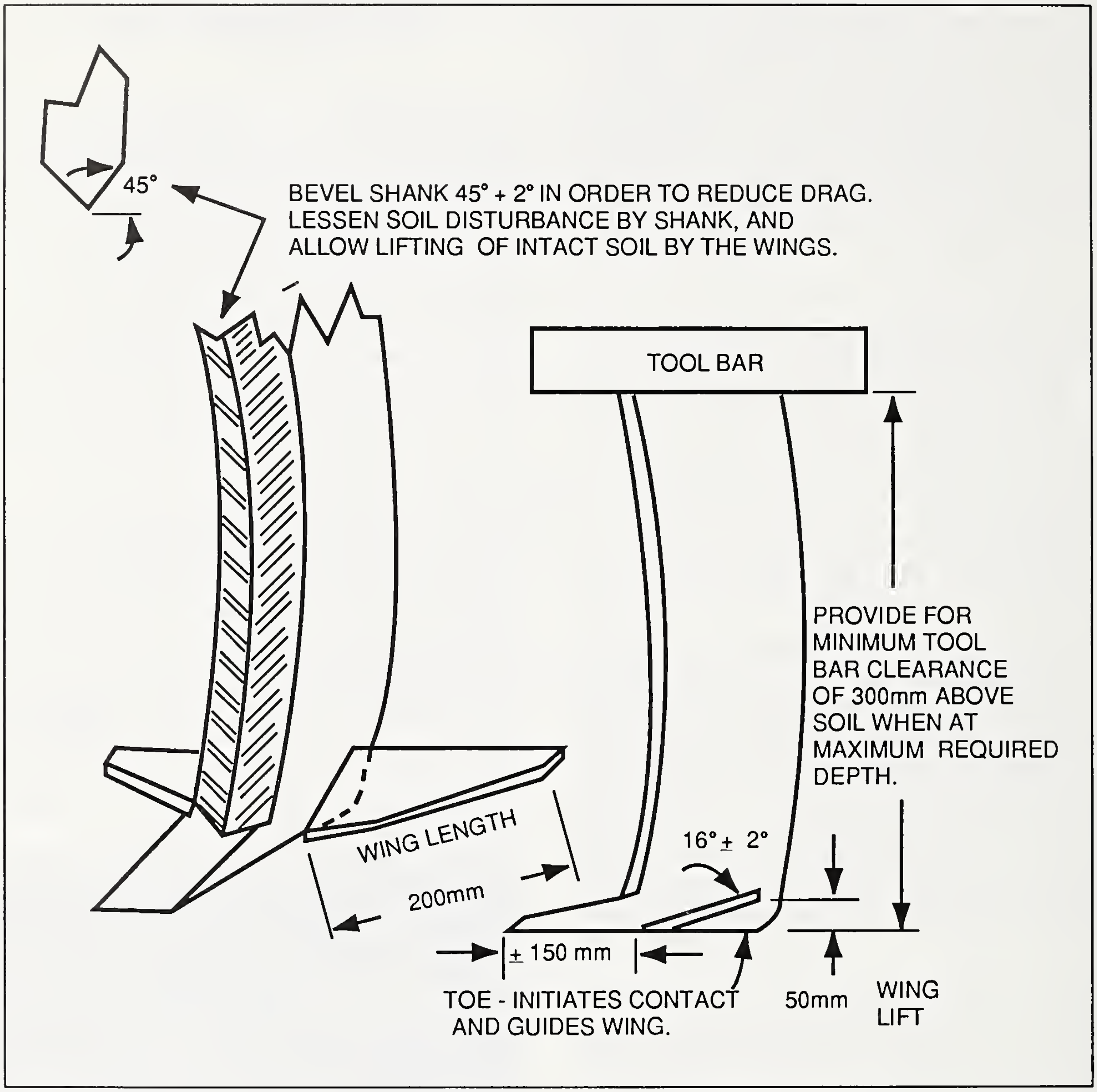


Figure 2.—*Tool bar-mounted subsoiling implement.*

NOTES:

1. Shank may be curved or straight.
2. Intended for use when operating three shanks over a two meter (eight feet) width.
3. Wings with too great an angle of lift may result in a plowing effect.

Rippers have been developed that increase the versatility of the excavator (ref. 44). These are fabricated from scratch—not to be confused with the lighter-weight commercially available attachments used to loosen soil prior to excavation—and are attached by pins to two sockets welded on the back of the bucket. The rippers function as the boom is drawn back and the bucket is fully curled. "Star" or "rock" teeth are the best type of teeth to use. See figure 3 for a detail of excavator bucket rippers.

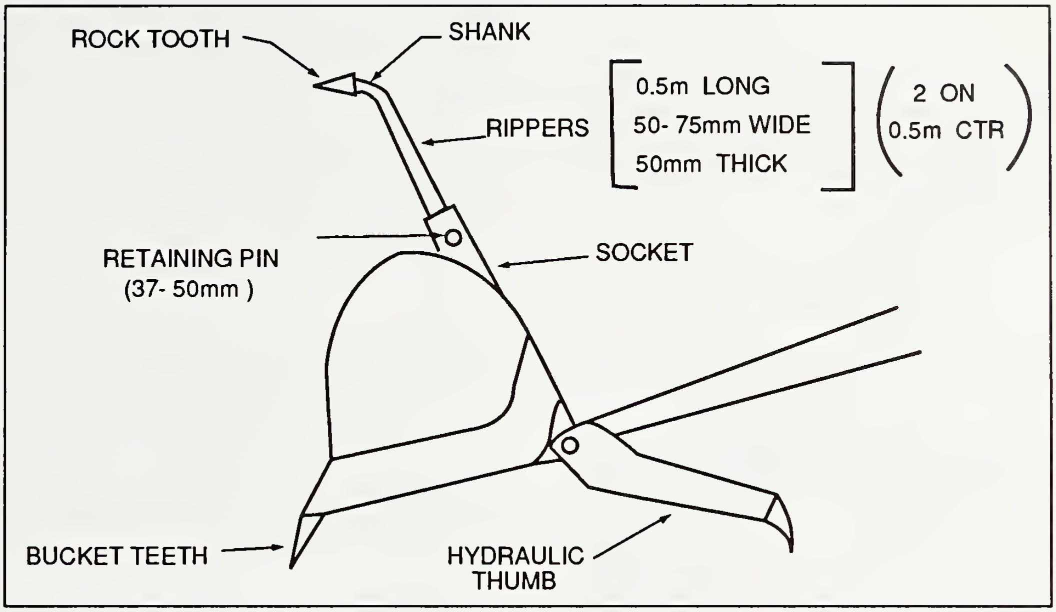


Figure 3.— *Excavator bucket rippers.*

"French drains" have been used to aid in reestablishment of subsurface flow intercepted by road cuts. See figure 4 for a conceptual design of a subsurface flow reestablishment system for installation during re-contouring. This system functions in a manner similar to the traditional french drain with a lightweight geo-composite product replacing the gravel flow medium.

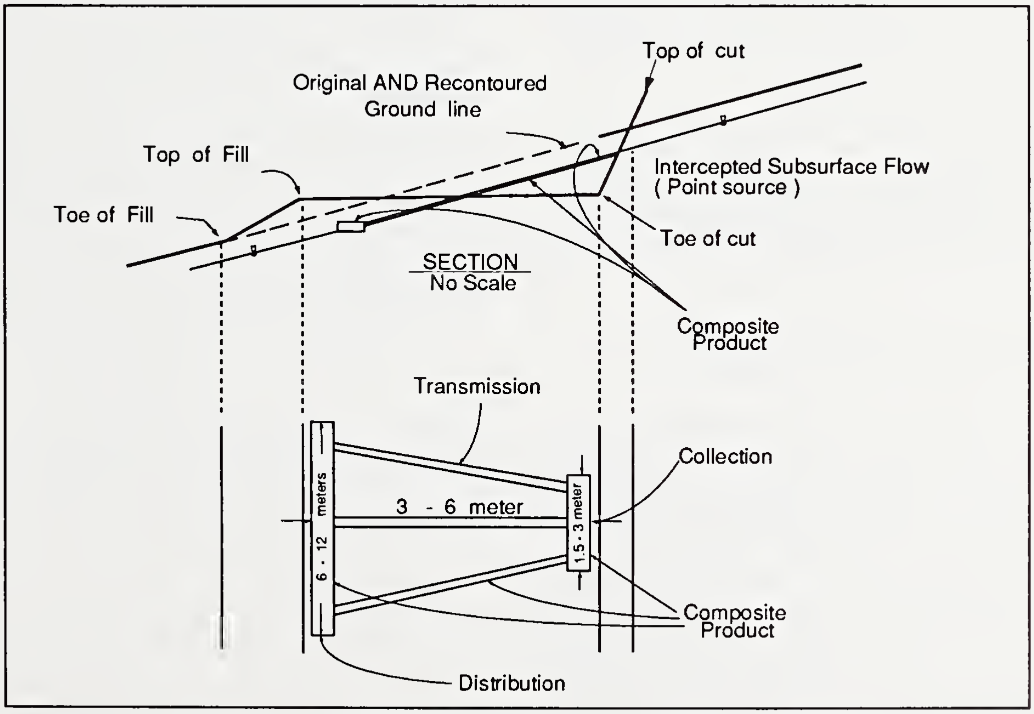


Figure 4.—*Conceptual design for road obliteration subsurface flow reestablishment system.*

NOTES:

1. Composite product consists of a plastic flow-through core wrapped in geotextile material and provides collection, transmission, and distribution of flow. Placement is defined by location of subsurface flow lines.

2. Collection and transmission mediums also distribute flow and provide storage.

3. Rip entire area around and under composite as required to ensure decompaction.

4. Account for soil properties, projected flow rates and volumes, percolation, and infiltration in system sizing and design.

5. Install system on a flat longitudinal grade (slope).

6. Geotextile filter must restrain only coarsest 15% of soil (D_{85} size) (ref. 3).

7. Geotextile filter permeability requirement: For cross plane flow, $K_f > (1 \text{ to } 10)\ K_s$ (use 10 for FS, when unsure of soil permeability) (ref. 3).

8. Geotextile must provide adequate drainage, prevent soil "piping" and exhibit required durability to survive installation.

9. Install collection portion of system to optimize flow from cutbank into composite. If necessary, provide sand blanket between seep and composite. Do not place geotextile in standing water or mud.

10. Install a PVC overflow to minimize risk of an excess hydrostatic pressure buildup.

Erosion

Limiting the area and duration of exposed soils minimizes erosion; timely stabilization and staged construction can minimize the amount of area disturbed and exposed at any one time. Retaining eroded materials on-site prevents sedimentation downstream. Filters such as silt fences, straw bales, or slash windrows, and settling ponds, sediment basins, and check dams help retain soil on-site.

Erosion and sedimentation control treatments begin by breaking up undesirable water concentrations and providing vegetative cover and organics to soil. Chipping and spreading slash on roadway surfaces and disturbed areas protects soil from erosion, retains moisture, and provides organic material (ref. 1, 2). Use of recycled paper mulch has limited erosion and aided revegetation of disturbed areas where other methods failed over decades of attempts (ref. 26).

Temporary seeding with rapidly growing annual grasses reduces erosion on sites not ready for permanent revegetation, while permanent seeding should be applied if revegetation is needed for more than one year. If an area is to remain denuded for more than 14 days or will be re-disturbed within 21 days, mulching without seeding should be considered (ref. 14).

Stability

Mass wasting sites are usually stabilized from the base up, although removing material from the top reduces instability. Placing buttresses of large rock (see figure 5) at the toe of slopes increases stability, resists undermining by streams, and provides a bench to catch slumping material. A rule of thumb is replacement of like volumes of soil—removed during road building or by water—with rock (ref. 5). The rock mass is forgiving and will yield while maintaining functionality, is porous, and can be made to grow vegetation. Place larger rocks at the base; angular rock rather than river run materials, which tend to be rounded, will increase interlock and stability. Buttress length and configuration is tailored to the site. Geotextile is installed prior to the rock in areas susceptible to erosion of fines by groundwater flow.

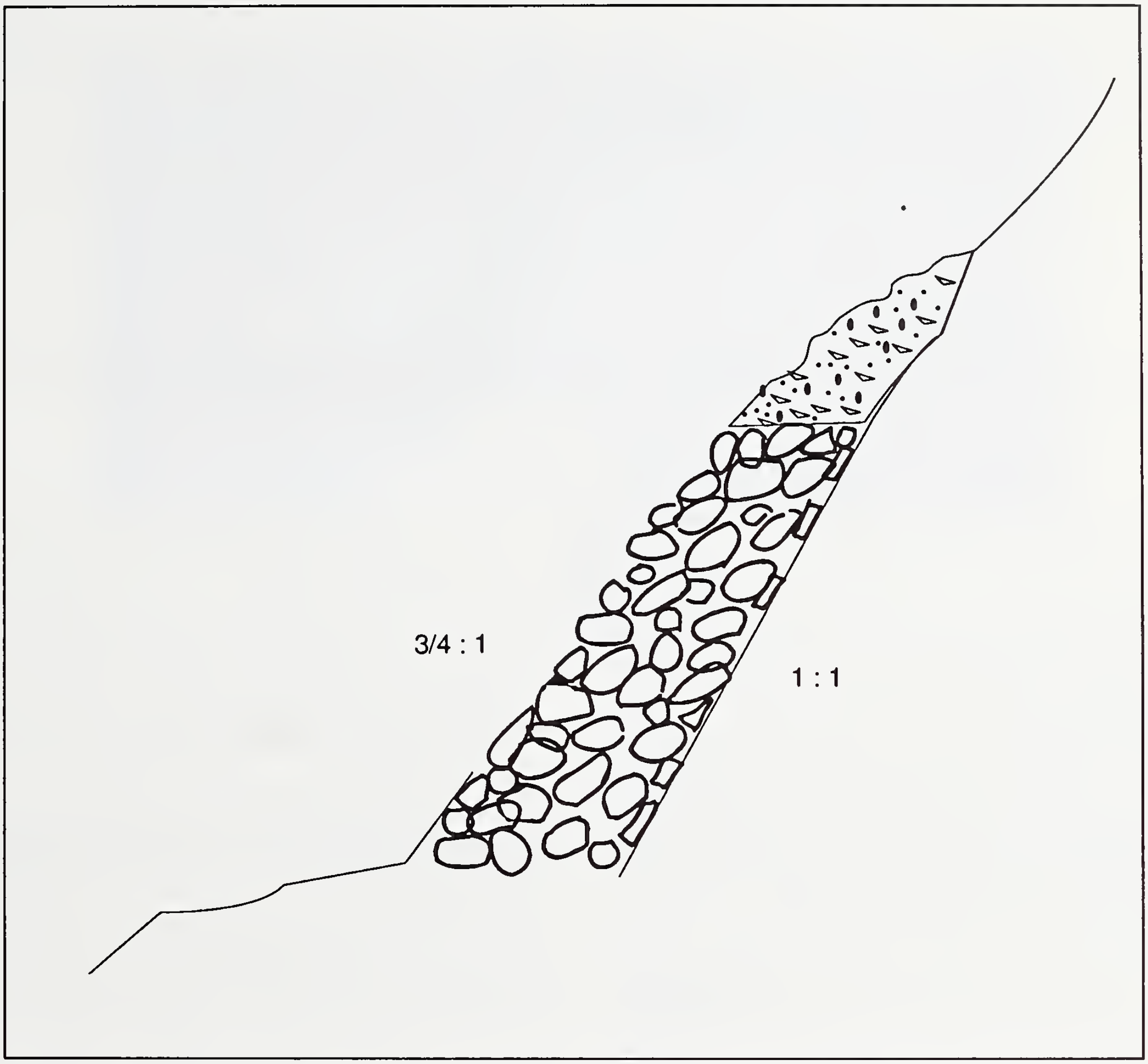


Figure 5.—*Rock buttress for increasing slope stability. Adapted from Beschta, 1991.*

Increasing Stability with Off-Site Materials and Products

Failure prone areas are often devoid of materials suitable for use in alleviating stability problems. Off-site materials and products used include timber and precast concrete logs, corrugated metal pipe, geosynthetics, gabions, chain link (ref. 40), and recycled materials such as tires (ref. 25).

Timber cribs installed at the base of a problem area provide a bench to support mass failures from further up the slope (see figure 6). The cribs will drain, but are subject to fire and will eventually require replacement, limiting them to short-term applications or use in conjunction with other treatments that develop over time such as vegetation. Using concrete logs or gabion baskets circumvents these shortcomings.

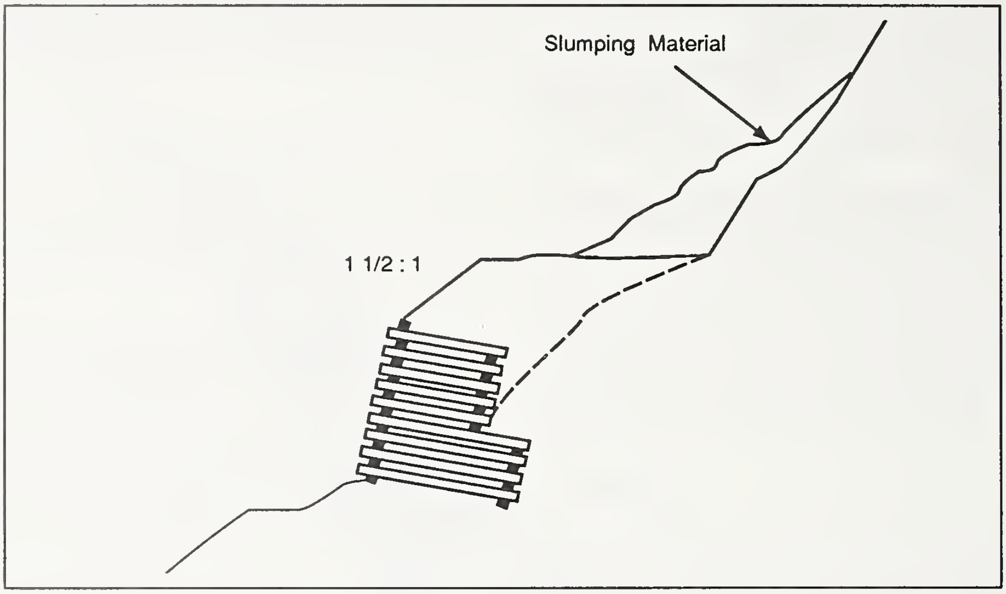


Figure 6.—*Timber crib for increasing slope stability. Adapted from Beschta, 1991.*

Corrugated metal pipe (CMP) cut along their cylindrical axes (see figure 7) (ref. 5) have been used in tiered structures backfilled with native soil.

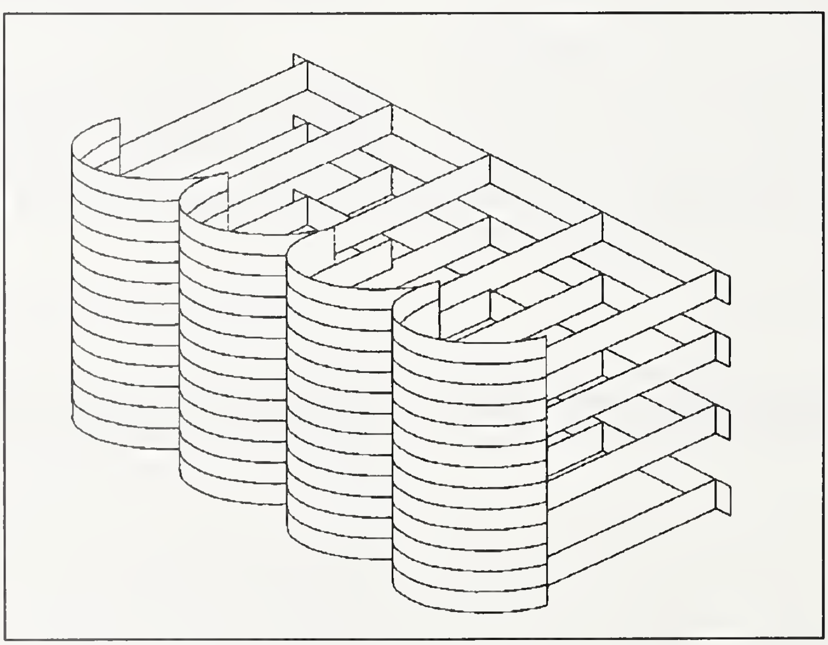


Figure 7.—*Culvert pipe tie-back wall.*

Geoweb products (ref. 35) also provide economical and aesthetic soil retaining structures (see figure 8).

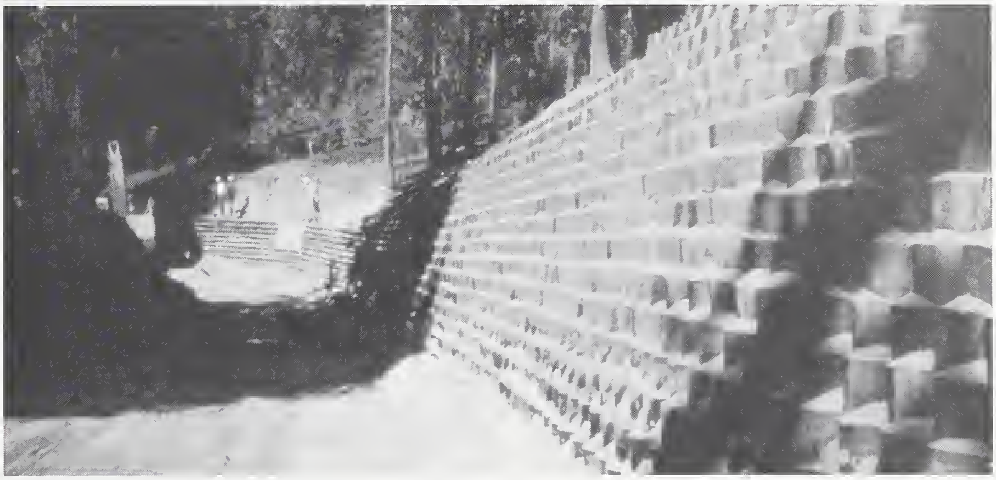


Figure 8.—*Geoweb soil-retaining gravity wall structure.*

Geo-grid has successfully been used in steep fill slide repair (ref. 32). Methods for protecting the face of reinforced soil fills and walls using treated timber, a straw-clay-manure-seed mixture, and fiberglass are under trial (ref. 8).

Geotextile fabric is used in retaining structures to provide tensile strength in much the same way that steel works in conventional reinforced earth-applications. The fabric functions as wall-face or in composite with other materials serving as facing elements (ref. 4). Asphalt coating the surfaces exposed to sunlight helps the fabric resist ultraviolet degradation. See figure 9 for drawings of a geotextile retaining structure, failure surface, and free body diagram. The failure wedge theory allows adequate analysis and calculation of required strength and embedment lengths for fabric reinforced earth walls (ref. 3). In these applications, fabric tensile strength should equal the plane strain strength of the surcharged backfill. Failure is usually defined by allowable structure deformation which dictates minimum fabric strength. Fabric creep under sustained loading must also be investigated. Some batter on the structure face reduces loading and may facilitate construction.

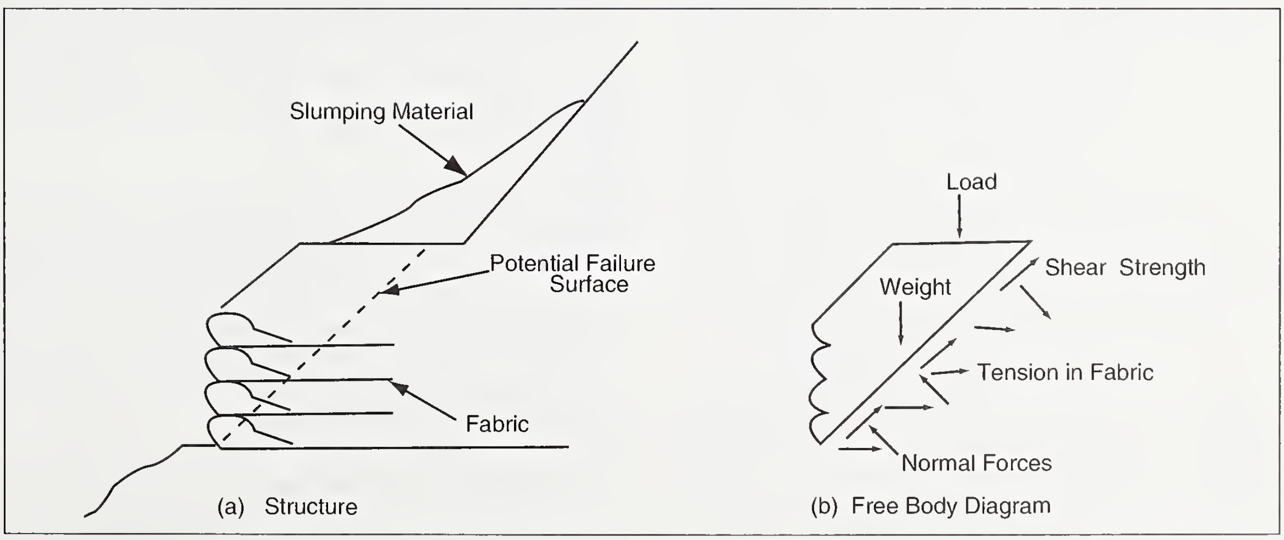


Figure 9.—*Geotextile-reinforced soil retaining structure. (Bell, 1990)*

Four basic retaining wall classifications exist: mechanically stabilized backfill (MSB), tieback, driven cantilever pile, and gravity. The Retaining Wall Design Guide (ref. 34) was developed to streamline and standardize the art and science of slope management. Numerous slope management approaches exist, including construction of retaining walls, rerouting, draining slopes (with surface, trench, and horizontal drains), cutting and reshaping slopes, filling, rock bolting, and consolidation grouting. In determining the most desirable method, many factors must be considered, including engineering feasibility, long-term performance, economics, aesthetics, intended use, the environment, required duration, and geology and geotectonics.

Revegetation

Site-specific treatments supporting revegetation include decompaction, placement of organic debris, soil, logs, and rock; fertilizing, mulching, chip and spread of slash; and seeding, vegetative plantings, and transplantings. Planting pockets, stepped slopes, and silt traps retain moisture and provide protection for seedlings. Some Forest Service units seed with grasses palatable to wildlife, balancing exotic versus native species. The dangers of introducing noxious weeds, survival rates, cost, seeding season, and short and long term vegetation goals and needs are site-specific in nature and require the attention of resource specialists.

A promising revegetation technique is use of the vetiver grass hedge (ref. 38). Vetiver is a relatively large, very tough bunch grass having a clustered mass of dense stems. Its sod-forming interlocking roots grow amazingly fast and penetrate up to three meters deep, forming a conical shaped root wad one-half meter wide that minimizes effect to nearby crops. The vetiver plant crown exists slightly below the surface; grazing and trampling inflict no lasting damage upon the plant. The crown is self rising to match silt levels. Vetiver has been known to survive drought, fire, windstorms, grazing, and submersion for up to 45 days.

The stems grow dense enough to block weeds and creeping grasses, also helping prevent the spread of ground creeping fires. Vetiver survives in an amazing range of soils and climates, elevations to 2600 meters, precipitation levels between 200 and 6000 millimeters, and temperatures from -9 degrees to +46 degrees centigrade. The grass is propagated by root divisions of slips; a clump is pulled off the main plant and inserted in a prepared hole in the soil.

Perhaps vetiver's gravest limitation is its restriction to warm climates. The grass is documented as surviving -10 degree centigrade temperatures in the state of Georgia, but died when temperatures fell to -15 degrees. Vetiver is also susceptible to termites, beetle grubs, and stem borers.

Prism Treatment Prescriptions

Prism treatments modify, reduce, or eliminate road-induced changes to natural topography, allowing some duplication of natural forms and encouragement of positive trending in natural processes. These concepts are highlighted by contrasting the forms with the probable worst case scenario in terms of undesirable influences to the natural drainage and topography due to low volume road prisms—an insloped section with a berm on the outside shoulder. Lessening cut and fill slopes aids in restoring drainage, reducing erosion and instabilities, and facilitating revegetation.

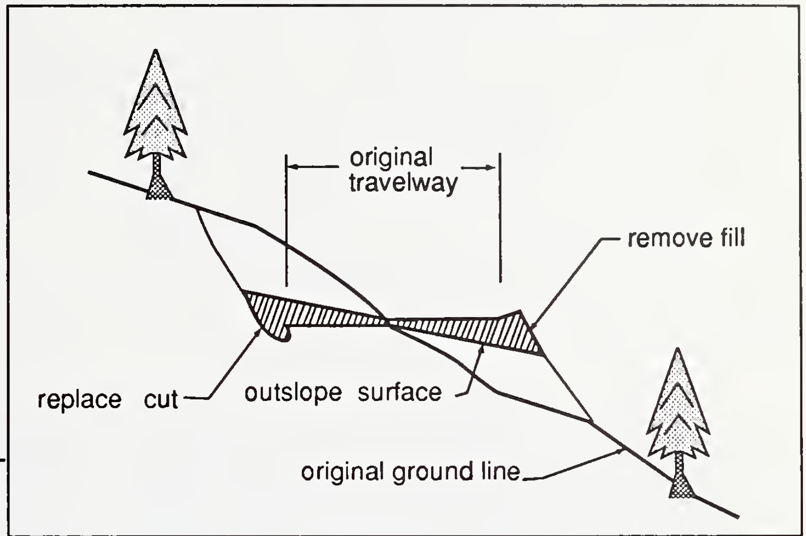
The stabilities of roadway slopes are increased by removing material from the top of fill slopes and by placing material at the toe of cut slopes. Site-specific investigation into risk, long-term stability, and the factors contributing to possible failure is required to determine which fills are critical and should be partially or completely removed. Prism treatment prescriptions include slope break rounding, the self-balanced outslope (see figure 10), the outsloping cut (see figure 11), the outsloping fill (see figure 12), the partial re-contour (see figure 13), and the full re-contour (see the section entitled "A LOW VOLUME ROAD RE-CONTOURING TECHNIQUE."

The self-balanced outslope is designed to economically fill ditches and remove berms, if any, shed water, reduce erosion, and stabilize cut and fill slopes. Outslope increases with increasing road grade and should be greater than three percent. Other cut and fill slope treatments include stepped cuts, erosion control trenching, debris and rock placements, vegetative plantings, and seeding.

Outsloping cuts and fills perform functions similar to the self-balanced outslope while generating or wasting material, respectively. Use the cut as appropriate with targets to generate material needed for treatments

on other road segments, and the fill as appropriate with targets to provide a waste site for excess material generated on other segments. The partial re-contour stabilizes cut and fill slopes while leaving a portion of the travelway intact. Reducing the width of the travelway increases environmental sensitivity and can provide trails for enhanced recreational opportunities.

Figure 10.—*Self-balanced outslope.*



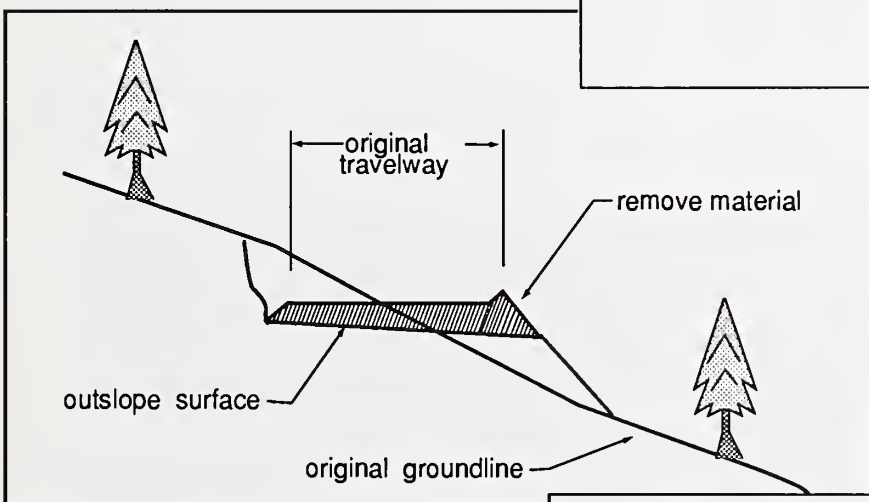
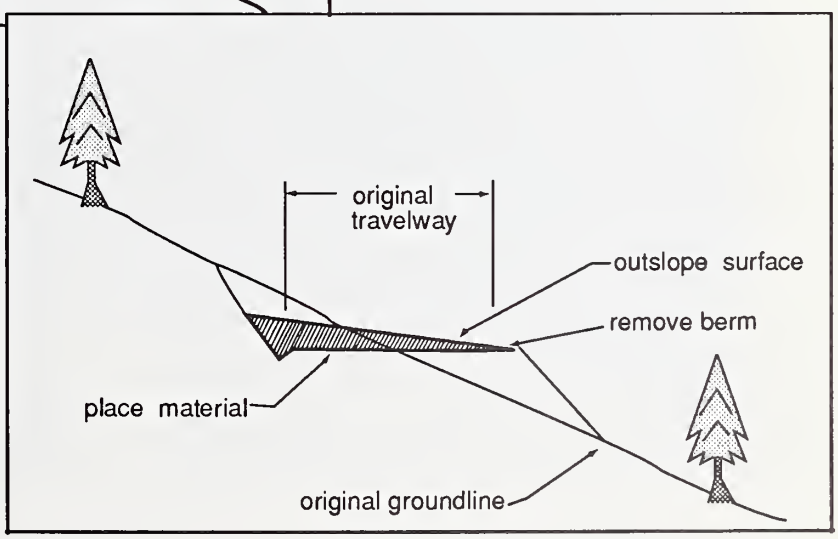


Figure 11.—*Outsloping cut.*

Figure 12.—*Outsloping fill.*



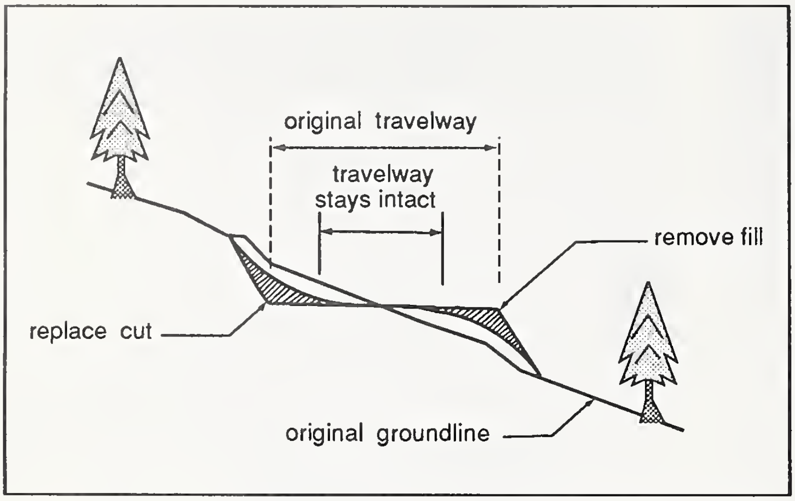


Figure 13.— *Partial re-contour.*

Full re-contouring is utilized on prisms as dictated by conditions in priority areas or by cumulative effects problems. Embankment material is removed and replaced in areas where excavation occurred during construction to approximate the original topography. Included may be removal of drainage structures, decompaction, efforts to reestablish subsurface flow, debris and rock placements, vegetative plantings, seeding, mulching, and treatments to drainages and adjacent areas.

A Low Volume Road Re-Contouring Technique

The re-contouring technique described here is considered the highest attainable level of mechanical obliteration and hydrologic restoration for low volume roads (ref. 29). Efforts are made to initiate trending that will return the road corridor and undesirably affected adjacent areas to approximate natural or desired condition and function. This includes reestablishing original contour—removing embankments and replacing cuts—removing drainage structures, reestablishment of subsurface flow, debris and rock placements, treatments to gullies and their connectivity to stream systems, and vegetative plantings, seeding, and mulching. The attempt is made to generically describe these efforts; to this end, experience from Regions 1, 2, and 6 is drawn upon.

Many Forest Service units begin C & O projects by executing mechanical obliteration work under equipment rental agreements (ref. 23, 39, 45). This facilitates gaining experience on the ground and expedites smaller projects, while allowing the flexibility to experiment with alternative techniques and equipment. Other benefits include ease in modifying the work plan (ref. 24). Cautionary notes are made, however, that constant inspection is required (ref. 37), and that success is largely determined by the skill and experience of contract inspectors as well as equipment operators. Equipment rental for large projects may prove uneconomical and lead to conflicts between operators (ref. 39). Once experience is gained and techniques refined for an area, solicitation of work through public works contracts can allow more effective and economical project implementation.

Heavy equipment used includes crawler tractors, excavators with hydraulic thumbs, front-end loaders, backhoes, dump trucks, and climbing backhoes, all of which should be appropriately sized to the job.

This re-contouring technique involves two passes with an 18,000 kilogram (40,000 lb) class excavator and was developed for 4.3 meter (14 foot) wide side-cast roads on steep side slopes. The two pass technique is considered the worst-case scenario; roads on gentle to moderate side slopes may be re-contoured in one pass. Landings and roads on steep slopes may require alternative techniques and equipment; the excavator may not be economical if material must be handled multiple times. Realize that the order of the first three items here may require adjustment; the work may be completed in stages; and modifications to the technique may be necessary for other needs or geographic areas.

- Materials required in post-obliteration treatments are stockpiled at points of opportunity adjacent to the road (ref. 45). These include seedlings or plants, seed, mulch, fertilizer, and materials required for drainage restoration or monitoring. Large woody debris and rock to be spread within or adjacent to the corridor or in reshaped drainages is also collected and strategically placed.

- Required pre-obliteration removal of road appurtenances and treatments to adjacent areas are completed. This includes any work requiring access such as removal of structures, salvage of surfacing, land form modification or stabilization, skid trail and spur road treatments, drainage network and canyon bottom treatments (a climbing backhoe may expedite this work), and silvicultural/fire treatments.

- Fill material deemed as excess to project needs can be excavated, hauled, and wasted off-site.

  Large embankments requiring tractors, front end loaders, and end dumps for economical reduction are worked from sites furthest-in prior to the recontouring operation. An excavator may later shape these sites.

- The travelway width including turnouts and landings is ripped with excavator bucket rippers or a crawler tractor, if necessary to facilitate excavation, increase hydraulic conductivity, or break up the road surface "slip plane" and provide interlock with material placed on it.

- Subsurface flow reestablishment systems are installed, if required.

- Excavator makes two passes in the recontouring operation. Starting at the beginning of the road segment to be re-contoured, a 0.3 to 1.0 meter (1 to 3 foot) high operating "platform" (see figure 14) is built that allows the machine to reach the top of cut and provides a bench to support material placed on the cut slope.

- Platform width must provide operating stability yet should avoid encroaching on the fill. A higher top-of-cut dictates a higher platform; a platform may not be needed on gentle slopes or when the machine can easily replace material at the top-of-cut.

  The material for this platform comes from the side-cast embankment as far down the fill slope as the machine can reach while operating from the platform. Efforts are made to provide a smooth transition from the top-of-cut to replaced material.

Figure 14.—*Excavator, on platform, obliterating a road prism.*

- A “pioneer road” is excavated to provide access for the second pass, at a level low enough to allow the machine to easily reach the toe-of-fill (see figure 15). The excavator, operating on the platform, continues to pull reachable fill, replacing it from the top-of-cut down to the platform.

- Materials encountered during the operation suitable for specific use in the project such as top soil or rock are salvaged and stockpiled.

- On the second pass (in the reverse direction) the excavator operates from the pioneer road to reach the toe-of-fill, removing all remaining embankment material and placing it where needed. Channel crossings are restored as discussed in the channel crossing restoration section below.

  As the excavator works out, it obliterates the pioneer road (see figure 15), effectively completing the recontouring operation. Slopes are dressed, high and low points smoothed, and the surface left in a roughened condition to increase moisture holding capabilities and facilitate revegetation.

  Final placement of large woody debris and rocks is made on the re-contoured slopes at this time. Large woody debris is well placed parallel to the contour; care should be taken to keep it out of the new embankment. Small trees and shrubs may be transplanted from surrounding areas.

- Work crews conduct revegetation activities.

See figure 16, the restored hillside.

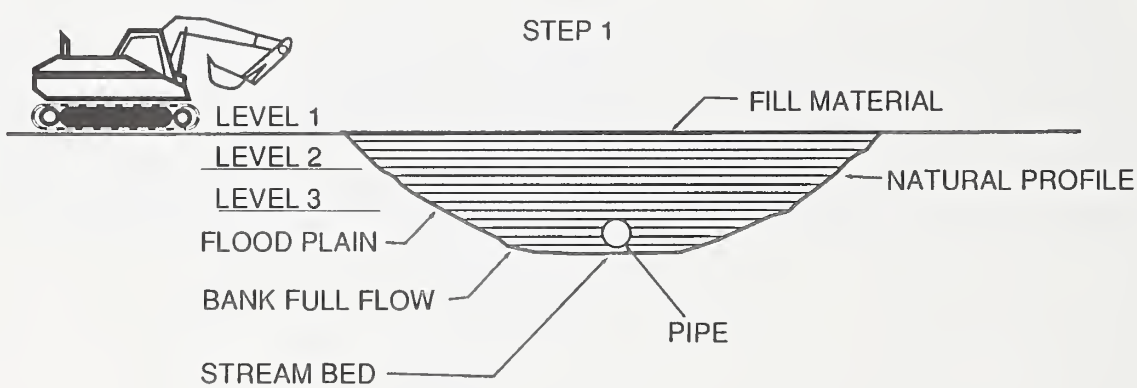
Figure 15.—*Pioneer road for obilterating a road prism.*

Figure 16.—*Restored hillside.*

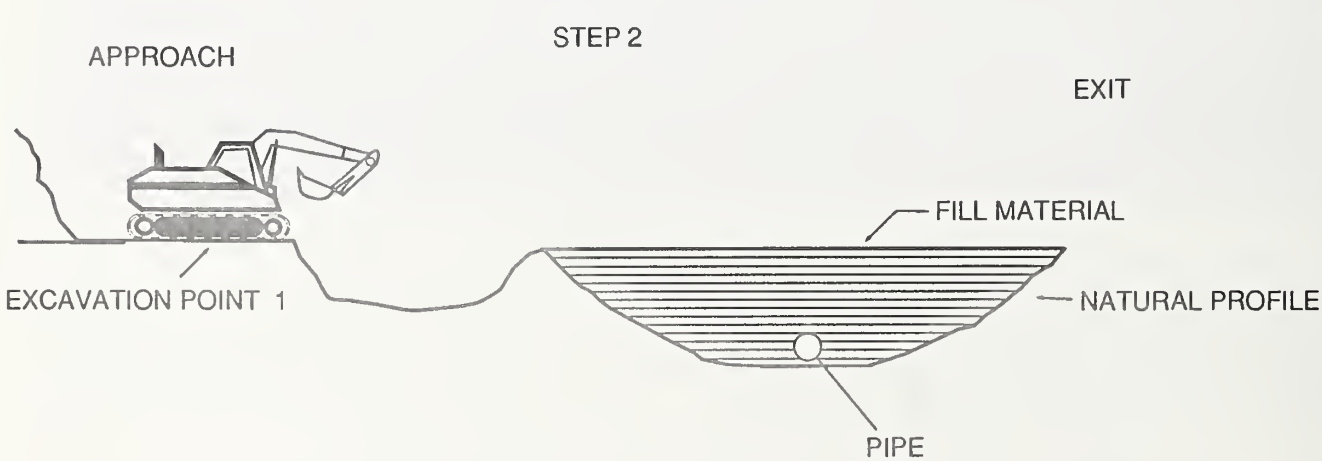
A Channel Crossing Restoration Technique

The basic channel crossing restoration technique for low volume roads (ref. 16) makes use of an 18,000 kilogram (40,000 lb) class excavator and is applicable to fills ranging from 4.5 to 9 meters (15 to 30 feet) deep. Three or four operating levels and six or seven excavation points are required. It must be noted that the pipe is not always located in the channel bottom as shown; the pipe outlet may be "perched" on fill material, or the pipe may have been installed at a skew to the drainage path to simplify bedding and backfill by distancing it from the stream, which subsequently is diverted into the pipe. Channel restoration targets should account for pipe installation techniques if needed.

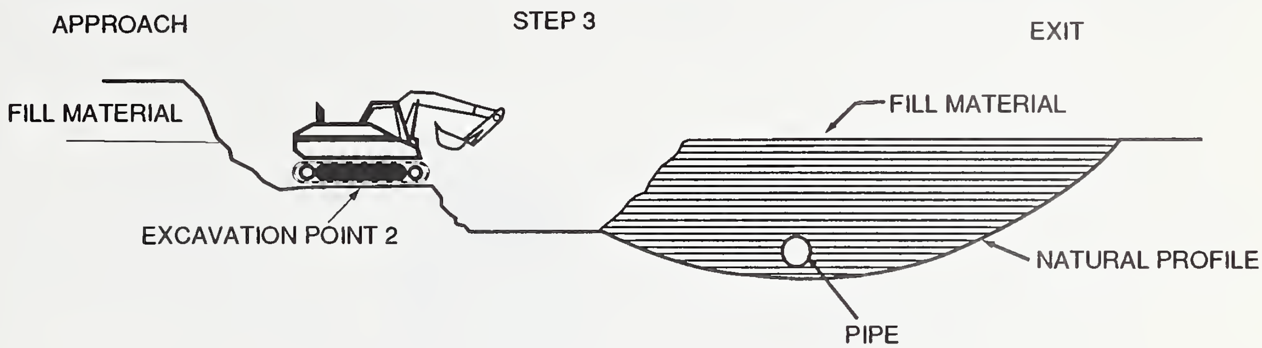
Use of crawler tractors to reduce the fill by drifting each way or use of front end loaders and dump trucks may prove more economical for steps two through five, although the excavator is best for special removal and placement of material, pipe removal, and shaping the site.



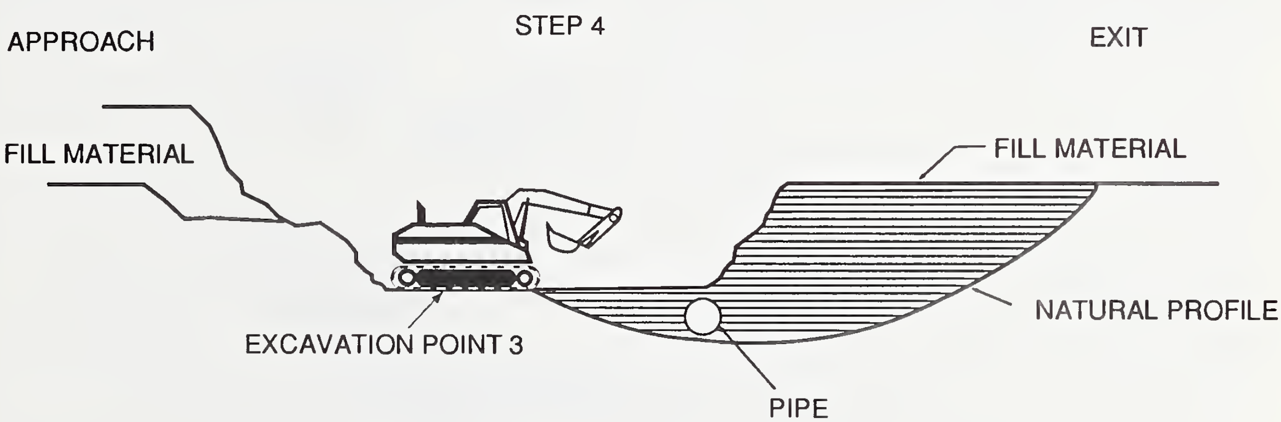
Excavation point 1 is on the approach to the fill and is at the road level. The next lower level is excavated from here and may not be in the actual fill. This is necessary to accommodate the large amount of fill to be removed, and may result in additional disturbance to soils and the site.



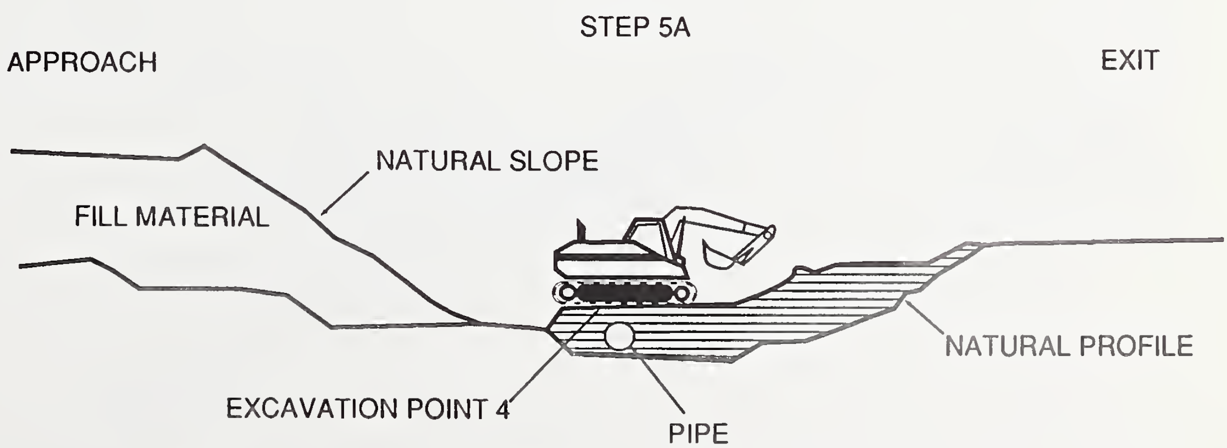
The excavator begins mass removal of fill from excavation point 2, in the process digging down to the next lower level, which should permit reaching maximum required depth.



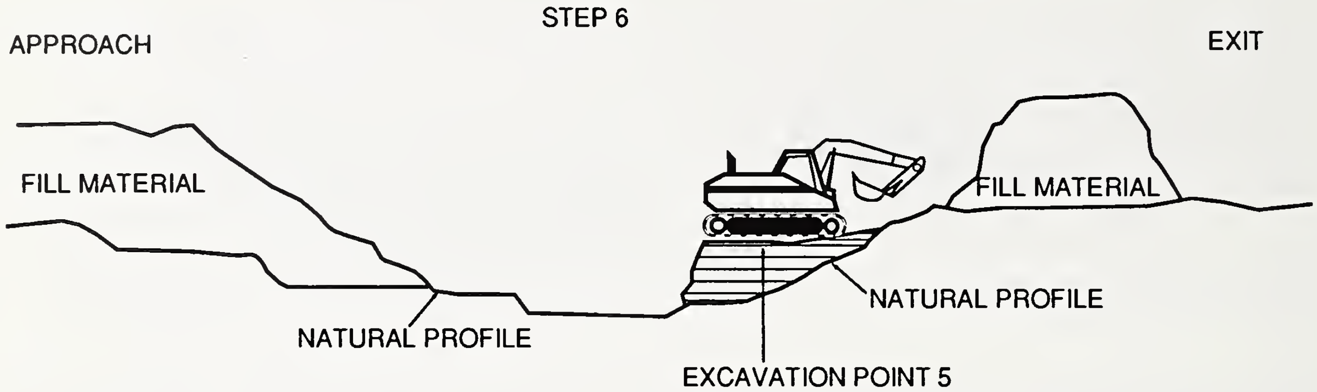
From excavation point 3 the excavator removes both fill upstream and downstream of the road centerline, until native soil—maybe difficult to identify— is encountered. Enough material must be left to provide a stable operating platform.



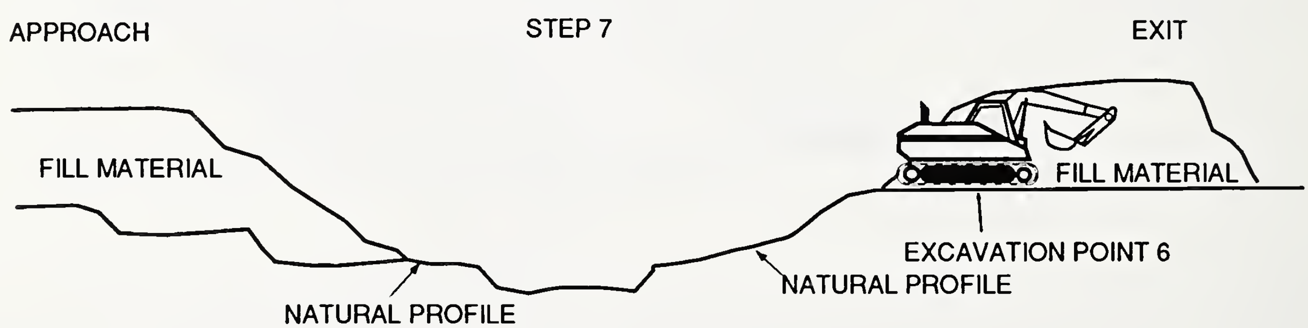
Excavation point 4 is directly over the low point of the channel, at the same level as point 3, from which the machine should be able to reach maximum depths required to remove all fill.



Excavation point 5 is on the ascending level. Remaining fill around the culvert is removed prior to removal of the pipe itself, after which disposal of the pipe may take place.

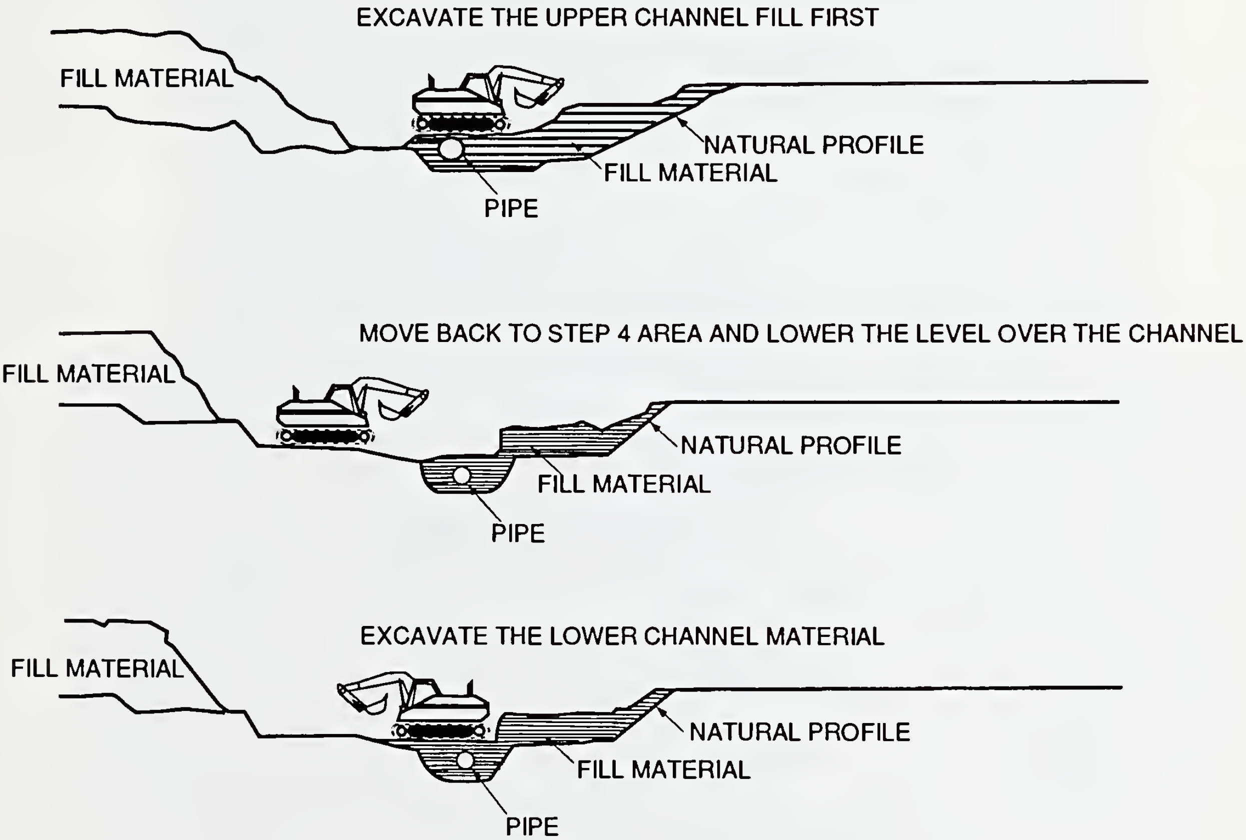


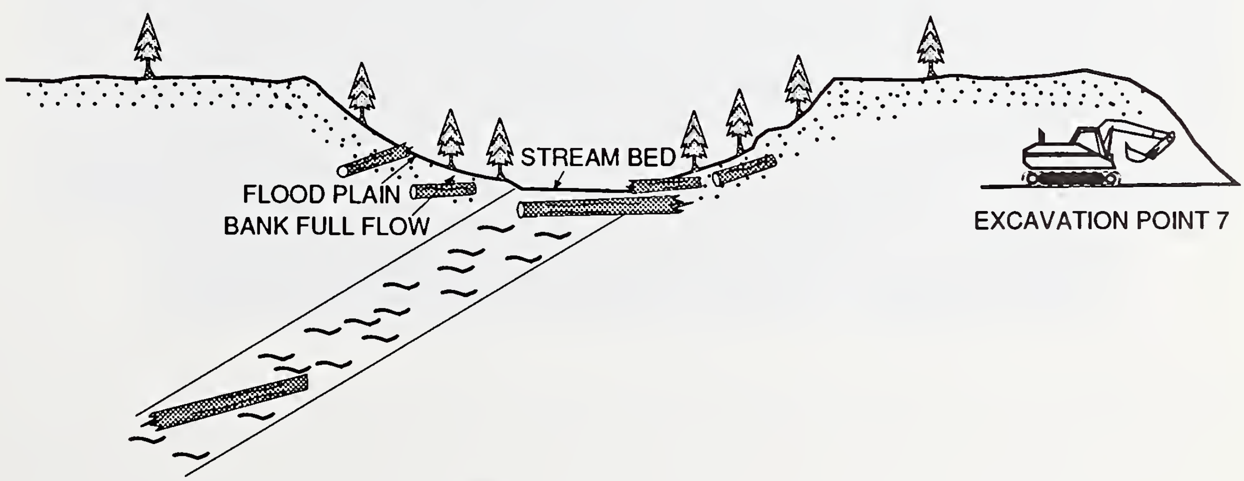
Excavation point 6 is again at the road surface level, from which all remaining fill is removed from the channel area. At this point, the profile and cross section of the entire channel area is restored and shaped. Rock armoring and woody debris may be placed at this time.



Fills deeper than 9 meters (30) feet may require the excavator to dig down to points 3, 4, and 5 towards the uphill side of the centerline first; separate excavation points are needed on the lower side due to the larger stretch of canyon length occupied by fill. Additional equipment may expedite removal of materials, or the excavator may require several steps—handling material several times—to clear the channel of material. Maximize use of the approach side for material storage.

STEP 5B





See figure 17, an excavator placing wood debris and rock in a restored channel.

Figure 17.—*Excavator placing large woody debris and rock in a restored channel.*

Some pointers on channel restoration are as follows:

- This technique results in the bulk of excavated material being placed on the approach side of the channel. Efficiency is optimized by maximizing this quantity.

  Plan final deposition of material carefully as to needs in re-contouring adjacent road sections and the mass diagram for the overall project.

- Maintain natural bank full flow capacity as dictated by channel characteristics above and below the site.
- Remove material outside the channel that is susceptible to movement into the channel to prevent clogging, blockages, and sedimentation.
- In live streams, remove all fill around pipes prior to bypass and pipe removal. Use sediment traps and silt fences to minimize sedimentation during and after excavation and to minimize the total volume of contaminated water.
- Channel restoration inspection is critical to environmental sensitivity due to proximity to streams and flow routing potential.
- Construction staking of excavation and embankment facilitates locating excavation point 1 and placement of excavated material.
- Coordinate channel restoration efforts with other aspects of closure and obliteration work.
- Maintain safe and stable working platforms and conditions for all equipment and personnel.

Figure 18.—*Restored channel.*

Road C & O projects must include holistic evaluation and treatment of the entire watershed as a functioning unit, as consideration of the road corridor only will likely result in piecemeal, incomplete fixes. Treatments must be compatible with project targets.

Altering Flood Flows In Disturbed Areas

Consider constructing wetlands to aid in flood flow alteration—the process by which peak flows from runoff, surface flow, and precipitation are stored or delayed—in roads and disturbed areas exhibiting higher than natural peak flows (ref. 31). "Silt traps" may be more realistic terminology considering the eventual sedimentation that occurs. Hydrologic modeling aids constructed wetlands sizing, design, location, and ultimate success.

A constructed wetland can be installed almost anywhere (ref. 13). Valuable reference documents for constructing wetlands include "Agricultural Handbook No. 590," "Landscape Design: Ponds," "Engineering Field Manual for Conservation Practices, Chapter 11, Ponds and Reservoirs," "Water Quality Field Guide," and "National Food Security Act Manual," all of which are available from the Soil Conservation Service (ref. 18).

Effectiveness is optimized for new wetland sites high in the watershed when the ratio of wetland and surface water areas above to total area above is less than approximately seven percent, and for watersheds producing relatively high peak flows and water yields. Studies indicate that 50 percent of flood peak flow reduction results from the first 5 percent of wetland area in the watershed (ref. 31).

Areas with steep topography, high water tables, or shallow soils may be subject to severe flooding which limits performance of constructed wetlands. Sediment load inputs to wetlands receiving surface flows gradually reduces water capacity and buffering function over time.

A constructed wetland may be sized to store all or part of a particular frequency storm runoff volume. For wetlands exhibiting channel flow, a constricted outlet width less than 1/3 the wetland width during storm conditions is recommended. Alternatively, the cross sectional area of the outlet should be less than 1/3 of the cross sectional area of the inlet (ref. 31). Wetlands without channel flow should have outlets less than 10 percent as wide as the average wetland width. Sheet flows are generally desired over channel flows due to greater frictional resistance, reduced erosion, and de-synchronization of tributary flows. De-synchronization of headwater flow can increase flood event duration and reduce peak flow.

Flood flow alteration is most effective in densely vegetated wetlands with little open water. Dominant vegetation classes should be commercially available, forest or scrub/shrub species, tolerant of saturated soil, and preferably native to the region (ref. 31).

Gully Control

A gully is formed by concentrated flow, usually intermittent in nature, and is a relatively recent fixture on the landscape. Gully erosion is most prevalent in dry lands or in disturbed humid areas where soil compaction and vegetation removal have resulted in surface runoff. Once caused, it is difficult to control and costly to fix. Development of new gullies or the rapid rate of expansion and deepening of older gullies often can be traced to removal of vegetative cover through some human activity (ref. 7).

Successful gully control meshes mechanical means (check dams and armoring) with revegetation of adjacent sites. The effective dam has a spillway sized to accommodate expected peak flow. Spillways are effectively broad-crested weirs, the dimensions of which can be optimized using the fundamental form of all modern weir formulas (ref. 21):

$$Q = C_w L H^{3/2}$$

where Q = estimated peak discharge for the particular frequency of event, m^3/s (ft^3/s).

C_w is conservatively estimated in SI units at 1.65 (ref. 19) and in English units at 3.00.

L = average length of flow perpendicular to flow through weir, meters (ft).

H = depth of flow through weir, meters (ft).

See figure 19 for check dam cross sections through the spillway perpendicular to flow and parallel to flow.

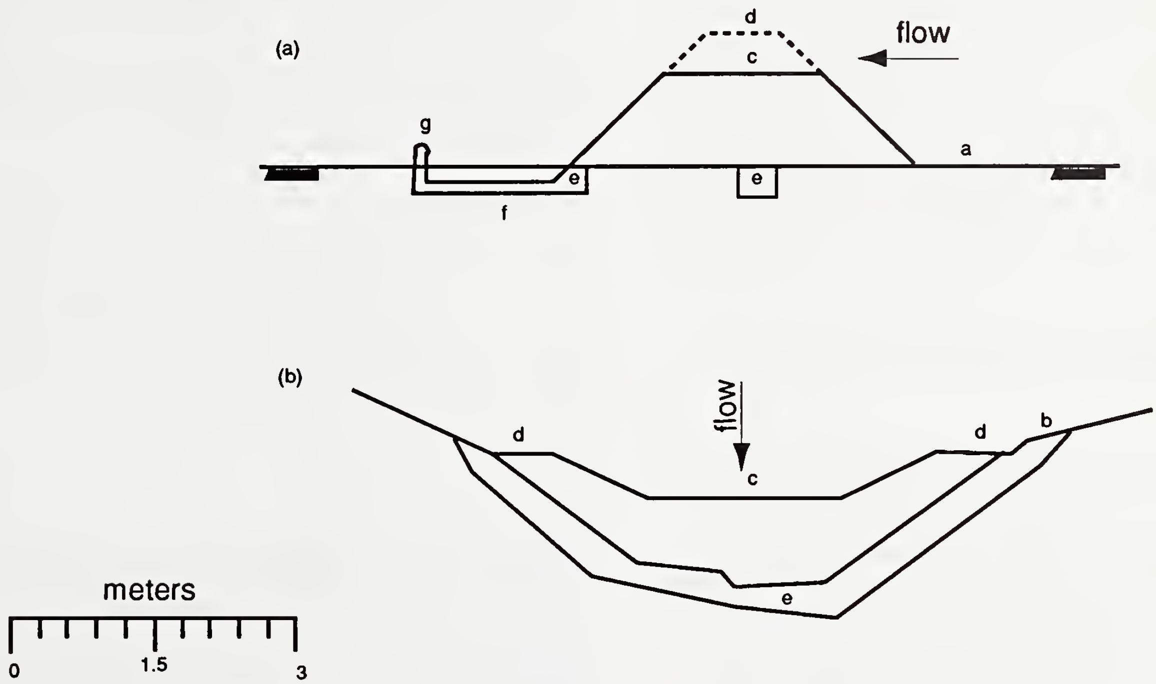


Figure 19.—*Check dam cross sections (Heede, 1976).*
a) Parallel to flow
b) Perpendicular to flow

a= original gully bottom; b= original gully cross section; c= spillway;
d= crest of freeboard; e= excavation for apron; f= splash apron; g= end sill

An apron downstream resists undercutting due to flow impact, while a sill on the lower end of the apron forms an energy absorbing hydraulic jump. Protective armoring of gully sides and bottom downstream also aids in resisting undercutting. Spillway geometry should balance spreading flow with protecting downstream gully sides; in narrow gullies, ensure flow does not wash gully sides. Keying the dam into gully sides and bottom increases stability and also resists undercutting and failure.

Placed rock effectively provides stable, porous dams. Minimize large voids in the dam by ensuring that 80% of rocky material is less than 150mm (5.5 inches) in largest dimension and that individual rocks are placed to form a dense, competent structure. Mineral competency ensures dam durability. Rocks should be round in shape, although some angularity aids in particle interlock.

Apron length should be 1.5 times spillway height for gullies with less than 15 percent bottom gradient and 1.75 times spillway height for gullies with greater than 15 percent. The apron surface should be 0.3 meter below original gully bottom, with a sill height 0.15 meter higher than original gully bottom to create an energy-dissipating pool.

Loose rock is effective armoring for gully sides and bottom downstream of the dam.

Individual dams are generally installed in the gully from the bottom up (ref. 7). The first dam is located in an area with no active down cutting, preferably near the gully mouth where it enters the stream system. This dam is sometimes referred to as a "gully plug." Other desirable sites include rock outcrops, on deposition, or hardened road crossings. The next dam is constructed upstream approximately where sedimentation from the first will end. Subsequent locations are dictated by sediment and gully bottom gradients, spillway height of the lower dam, and on-site conditions. The sediment behind the check dam is less steep than the raw gully bottom. The range of ratios of sediment to gully bottom gradient are as follows:

for course grained soils and sand:	0.3 to 0.6
for fine grained soils:	0.6 to 0.7

As a rule of thumb, steeper gully gradients dictate a smaller ratio.

A gully survey may facilitate dam location and design by furnishing plan, profile, and cross sections. Careful consideration of upland conditions, topography, and the gully system itself oftentimes reveals required sites and opportunities for optimal placement. Dams generally should be located at constrictions rather than wide spots in the gully cross section. Place dams above tributaries, below flow line meanders within a larger channel, and on rock outcrops where available.

Individual sediment deposits are maximized by building high dams spaced far apart. Stability is enhanced and gully gradients are stair-stepped—more closely matching original canyon slope—by installing short dams closer together.

Permanent gully control is accomplished only in conjunction with good hydrologic condition of surrounding slopes. Vegetation and plant litter is needed on eroding sites as well as where runoff concentrations originate (ref. 7). The most effective cover in gullies is characterized by high plant density, deep and dense root systems, and low plant height (ref. 19). Water concentrates without vegetation and organics, feeding gully development and making revegetation difficult due to less on-site moisture, drained soil, and lowered water tables.

The lower gradient of the sediment means less flow velocity and erosive force. This results in greater infiltration, leading to increased soil moisture and more successful revegetation, which in turn stabilizes soil and reduces peak flows. A stabilized gully bottom allows gully sides to attain the natural angle of repose of the soil. Mechanically slough over steep gully banks only after the bottom has been stabilized by vegetation. Revegetation alone is rarely successful in stabilizing head cuts due to concentrated flow.

Mechanical treatments to loosen compacted soils and reduce effects from landings, skid trails, and other disturbed areas may be required in conjunction with flood flow alteration, gully check-damming, and revegetation efforts to optimize C & O project effectiveness. Treatments requiring access must be completed prior to road obliteration.

CONCLUSIONS

Understanding the effects of roads and other disturbances on natural hydrology and identifying them in the field are prerequisites to effective closure and obliteration projects. Roads can concentrate water and inflict damage on natural fluvial systems; effects can accumulate when combined with other disturbances in the forest.

Each unique segment of an unneeded road should receive specifically designed treatments which range from simple abandonment to full re-contouring. Re-contouring and channel restoration techniques using standard heavy equipment have been developed for low volume roads in steep forested terrain.

Priorities in road closure and obliteration include access, drainage, stability, erosion, and revegetation. Alteration of one of these interrelated factors results in adjustments among the others. Identified priorities lead to desirable targets, which are attained by site-specific treatments.

The successful closure and obliteration program is based on complete inventories, is sufficiently funded and contains ample lead time, is systems-process oriented, involves the public, is in compliance with environmental laws and regulations, and relies on resource specialist input and effectiveness monitoring.

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Appendix A

Road And Land Modification Effects On Natural Hydrology

Past transportation system development priorities emphasized access, safety, and economics. "Environmental concerns" usually referred to operational or maintenance problems, such as rutting and erosion, plugged drainage structures, mass failures, or reduced access.

Forest Service land managers often describe road "densities" in terms of the sum of road prism lengths in a watershed divided by watershed area. The effects of one kilometer of road per square kilometer (1.6 mi/mi^2) of watershed area on environmental health in most forested areas is negligible. Escalate the density to five km/km^2 (8 mi/mi^2) (some areas reportedly have in excess of twelve!) add land disturbances, and the potential for adverse effects increases dramatically.

Inspections of hypothetical streamflow hydrographs and water budgets for a typical medium-sized forested watershed before and after roading illustrate some undesirable effects. The hydrograph represents discharge—including surface and subsurface flows, and baseflow—versus time (see figure A1).

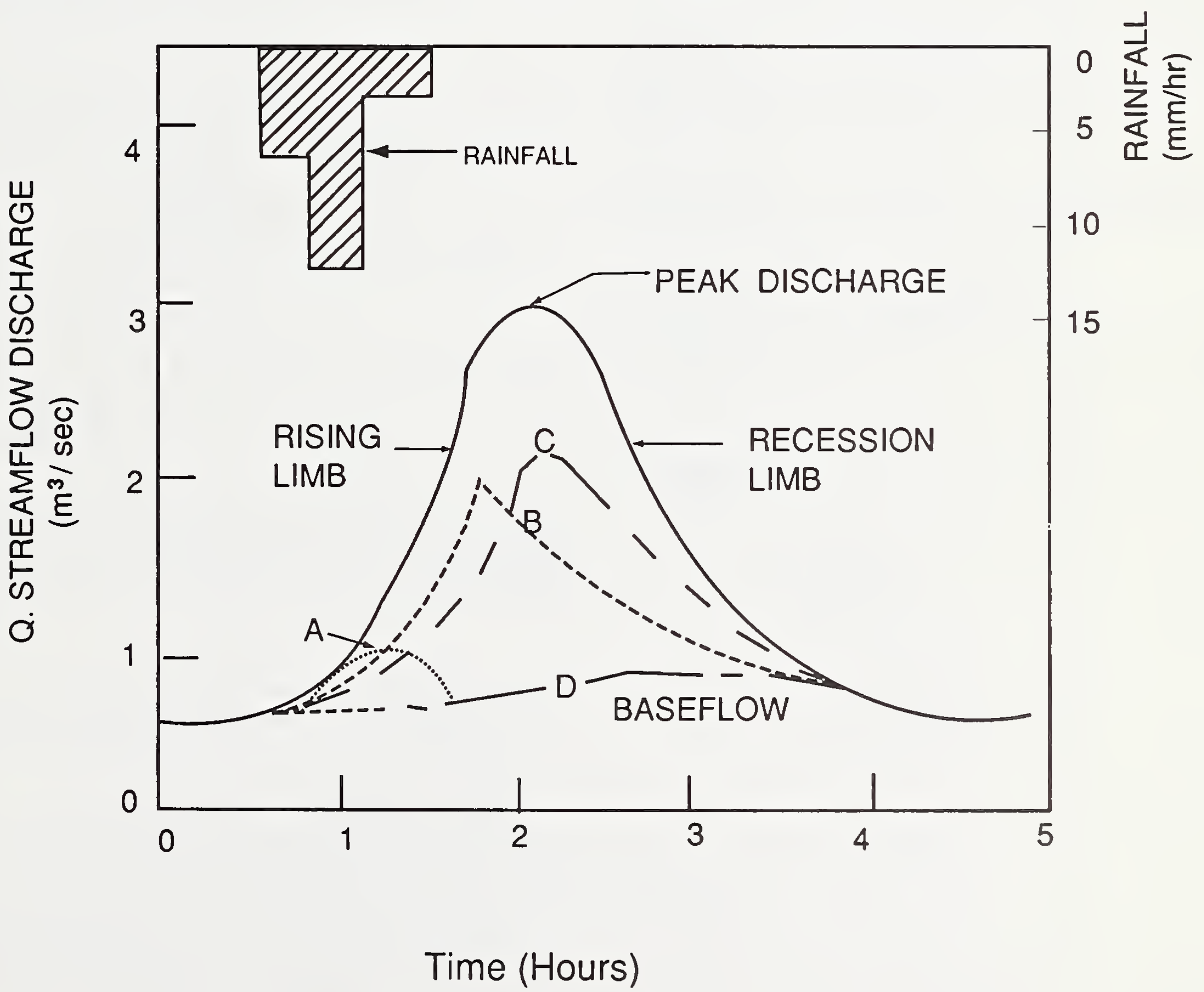

Figure A1.—Relationship between pathways of flow from a watershed and the resultant stream flow hydrograph. A=channel interception; B=surface runoff, or overland flow; C=subsurface flow, or interflow; D=groundwater, or baseflow; Q=stream flow discharge. Brooks, et al (1991)

Forest cover promotes a higher quality discharge in a less erratic manner than most other watershed conditions. Precipitation falling on undisturbed forest soils rarely is converted directly to surface runoff (ref. 7). Rather, the moisture evaporates, or is captured, infiltrates, and moves through and is stored in soil pores. Here it becomes available to vegetation, is safely (relatively slowly) released to subsurface flow and baseflow, or becomes vertical seepage.

See figure A2 for a flow chart depicting hydrologic processes and runoff relationships commonly found in generalized continuous simulation models.

Road building introduces steepened slopes, hardened surfaces, exposed mineral soils, and interception of subsurface flow, all of which lead to concentrated water, expanded flow source areas, and increased drainage efficiency. Related ditches, drainage structure out flows, stream diversions, and ruts in the travelway itself can represent defined drainages where none before existed, allowing concentrated water to become quickly routed into surface flow (ref. 48).

A well-located road with well designed drainage on mid-slopes or near the ridge has negligible effect; distance from the canyon bottom allows flows off the road to slow enough to drop sediment loads and infiltrate.

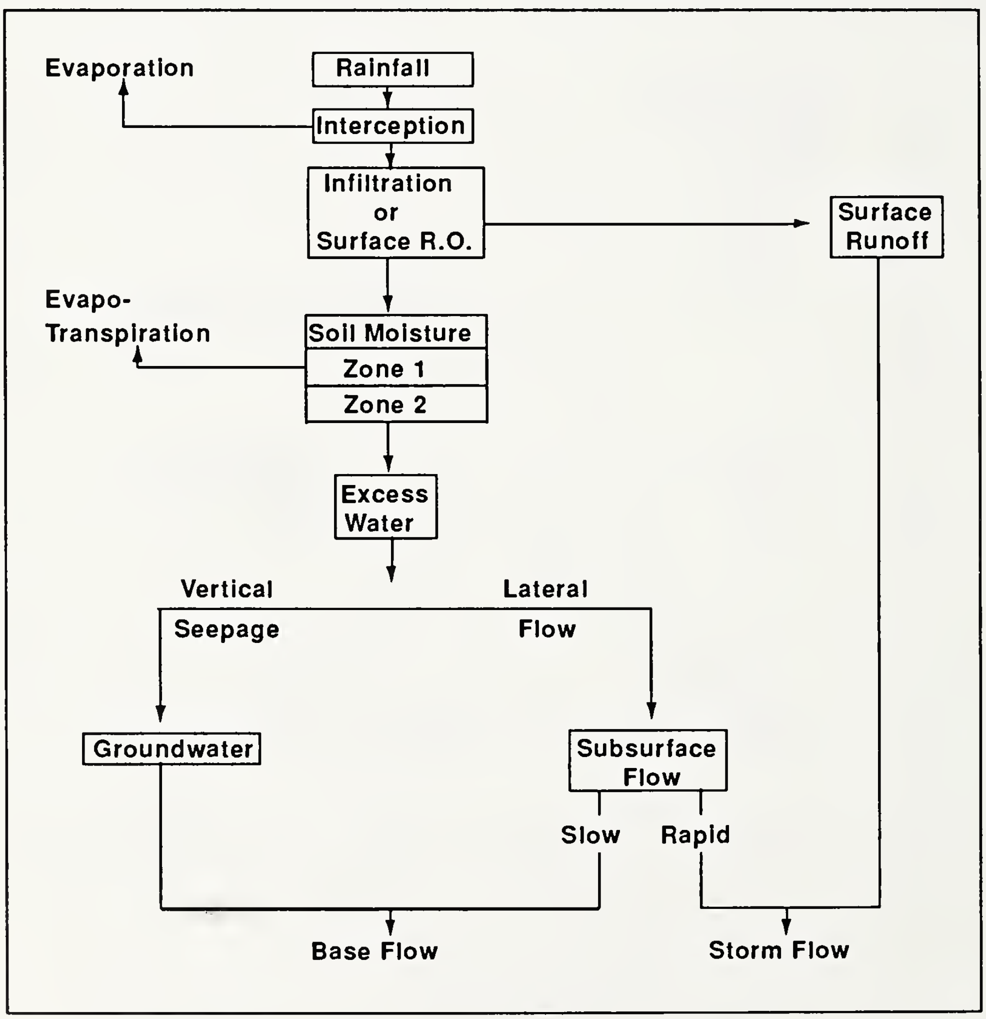

Figure A2.—*Hydrologic processes and runoff relationships commonly found in generalized continuous simulation models. Brook, et al (1991).*

Increase road density, include roads in close proximity to streams, and add disturbances to surrounding slopes, and surface flows may sufficiently accumulate to decrease the time of concentration and increase peak discharge out of the watershed. Surface flow increases—at the expense of groundwater and subsurface flow—and constitutes a debit to the long-term water budget by means of reduced base flow.

Reductions in deep seepage and groundwater recharge can also occur. The higher peak discharge occurs more rapidly, as less time exists for infiltration. The greater peak means increased erosion potential and additional damage possible to the drainage network. This combination can result in increased area under the storm hydrograph, higher water yield, and thus less moisture available for vegetation and future base flows.

Effects to hydrologic processes resulting from land modification can accumulate and be separated in time and space (ref. 17). Some road-related examples follow:

- Fines are alternatively generated by passing wheel loads and washed off the road into the stream by storm events.

- A single cross drain fails to pass a flow, initiating a cascade of over-topped pipes and/or a fill wash out down the road.

- Water concentration potential built into a road by insloping and/or leaving a berm on the down-hill shoulder results in severe gully erosion when an intense precipitation event occurs on saturated ground.

- A channel encroaching embankment suffers wash out damage during periodic flood events. Sedimentation occurs downstream.

- Years after construction, a stream diversion is initiated by a plugged drainage structure. A uniform road grade rather than a sag vertical curve over the pipe provides an alternative flow path. A new channel is cut along the road ditch line and results in heavy sedimentation downstream.

- Decades after construction stumps supporting side cast fills on steep slopes begin to rot, initiating mass wasting of fills and contributing to debris torrents flowing directly into streams.

- Cross drains inverts installed below meadow elevation cause gully formation upstream and require relief ditching downstream, resulting in concentrated flow at high velocities, lowered water tables, a drained soil-moisture "sponge," and dry land or less desirable vegetation regime invasions.

- Increased water yield due to timber harvest contributes to sediment movement and erosion damage on the access road.

Cumulative effects from these occurrences and other land modifications may unbalance both terrestrial and aquatic ecosystems. Sediment pulses can migrate into stream networks for decades following road construction and management activities.

See Table A1 for indicators of the potential for undesirable environmental effects from roading and land disturbance.

Table A1.—*Indicators of potential for undesirable environmental effects.*

Road Related	Range	Description
Density	Low-High	Lower density reduces the potential for cumulative effects.
Location	Good-Poor	Well located roads, flatter grades, and distance from streams minimize alterations to hydrology and other undesirable effects.
Standards	Sensitive-Insensitive	Low cuts & fills, surfacing, frequent drains; and hardened ditches and outflows increase environmental sensitivity.
Construction Methods	Sensitive-Insensitive	Appropriate for topography, environment, soils, climate, traffic.
Site Related		
Topography	Gentle-Steep	Gentle slopes minimize cuts and fills, simplify drainage, stability.
Elevation	Low-High	Lower elevations offer milder climates, longer growing seasons.
Soils		
Particle Size	Course-Fine	Lower percent clay generally reduces erodibility.
Gradation	Well Graded-Cohesive	Well graded soil exhibits greater strength, resistance to erosion and freeze-thaw damage due to cohesion and intergranular strength.
Geology	Stable-Unstable	Dip of strata, mineralogy, depth of soils.
Geomorphology	Stable-Unstable	Watershed shape and amount of low-lying area affect peak flow; canyons broad or V-shaped; concave, convex, or linear slopes affect stability.
Land Cover	Dense-Sparse	Proper vegetation and well developed topsoil sustain hydrologic health.

Environment Related	Range	Description
Climate	Mild-Harsh	Warmer climate generally increases revegetation potential.
Elevation	Low-High	Lower elevation generally increase revegetation potential.
Precipitation Intensity	Low-High	Low intensity generally reduces runoff volume and erosion potential.
Levels	High-Low	High levels expand revegetation options and benefits.
Soils	Good-Poor	Mineral and organic content for revegetation and erosion resistance.
Growing Season	Long-Short	Long season expands opportunities for revegetation.
Revegetation	Easy-Difficult	Quick revegetation reduces potential for undesirable effects.
Cumulative Effects		
Utilization of Resources	Low Over-Utilization	Excessive timber harvest, grazing, mining, farming, borrow pits, and disturbed areas generally lead to undesirable effects.
Transportation System Disturbances	Few-Many	Skid trails, landings, and disturbed areas, soils, and vegetation, and damage to drainage networks compound undesirable effects.
Natural Processes	Mild-Catastrophic	Rain on snow, fire, uplift, etc., exacerbate undesirable effects of road and site disturbances

Appendix B

Locating Temporary Roads To Facilitate Their Obliteration

The planning and location of temporary roads requires special consideration to facilitate their obliteration. The definition of a temporary road as per WO AMENDMENT 7700-94-2 is as follows: "Roads associated with timber sale contracts not intended to be a part of the forest development transportation system and not necessary for resource management."

The principles of environmentally sensitive roads (ref. 36) apply to the location, planning, and construction of temporary roads. Additionally, the short term nature of use on temporary roads and the existence of specific knowledge on amounts and types of traffic involved suggest minimizing construction standards to absolute minimums as dictated by safety concerns, operational requirements, and the surrounding environment.

The duration of use of the temporary road should be minimized by postponing its construction as long as possible prior to use, and obliterating it as soon as feasible after use. Season-of-use should be specified and observed for temporary roads to minimize rutting, erosion, sedimentation, and water concentrations.

Plan, locate, design, and construct temporary roads with ease of obliteration as a priority. Rank alternative corridors not only according to construction, operation, and maintenance costs, but environmental effects and difficulty in mitigating modifications to hydrology and topography. Stockpile topsoil and duff for re-spreading after use or obliteration of the temporary road.

Cuts and fills, road width and length, and the number and size of turnouts and other widening should all be minimized, as should appurtenances including landings and skid trails. Likewise, minimize disturbance to the ground, soils, vegetation, and root mats. Horizontal and vertical alignments should conform to the natural contour as closely as possible. Outsloped rolls in the grade effectively break up water concentrations during use and can be crafted into silt traps and planting pockets during obliteration.

Consider using portable crossings rather than rock blankets over low-bearing capacity soils or CMP installed in soil embankments. Properly planned and installed, portable crossings can economically provide short-term access while minimizing disturbances to stream and channel. They are relatively easily removed and minimize sedimentation and other effects to water quality and fish habitat.

Appendix C

Basin Study Checklist

Objective: This basin study checklist is intended to provide an organizational framework for completing slope stability investigations and analysis at level I (drainage basin), level II (project), and level III (site-specific) scales.

Method: Develop a logical sequence or checklist for accomplishing an analysis. The checklist is not intended to duplicate other information or methods already covered but as a cross-reference to all sections in the guide.

Level I: *Courtney Cloyd, Forest Engineering Geologist, Siuslaw National Forest*

Introduction: A level I analysis is a relative landslide hazard evaluation for resource allocation (Prellwitz et al., 1983).

Suggested Checklist:

1. Project Objectives (What are we going to do?)

- See sections 1B, 1C.1, 1C.2, 1C.4, and 2.
- Identify those parts of an analysis area having a high probability of slope failure under natural conditions.
- Assess the extent to which roads and timber harvest will affect or be affected by the existing slope stability of the area.
- Determine the geologic materials and processes occurring in analysis areas as elements of cumulative effects assessments.
- Identify private property and facilities and public resources that might be at risk if landslides were to occur.
- Rule of Thumb: Work closely with those requesting the slope stability assessment to identify analysis area boundaries, as well as resources, property, and facilities potentially at risk.

2. Initial Literature Review (Past History)

- See sections 1B, 1C.4, and 2.
- Review:

  a. Published and in-house geologic maps and reports

  b. Existing landslide inventories

  c. Forest Soil Resource Inventory (SRI) or other soil mapping

  d. Rainfall/climate models

  e. Seismic hazard ratings.
- An overview of 1:40,000 and 1:24,000 aerial photography can be performed at this time.
- Rules of Thumb:

  a. Look for patterns of failure related to land forms: slope angle, aspect, position, or lithology; structure; or soil type.

  b. Look for relationships between the type of management activity and slope failure.

  c. Look for resources potentially at risk not previously identified.

3. Field Reconnaissance (Current Condition)

- See sections 1C.4 and 2.
- Check interpretations made in preliminary aerial photography review.
- Check mapped soils and geology against field units.

- Rules of Thumb:

    a. Tree and vegetation cover often masks existing failures.

    b. Hydrophilic and dry-site vegetation may help characterize basic ground water/soil moisture conditions.

    c. Hummocky slope surfaces, and/or pistol-butted, bent, bowed, or leaning trees may indicate slow, relatively recent slope movement where other evidence is absent. However, pistol-butted trees may also be the result of snow loads.

4. Data Synthesis and Initial Hypothesis

- See sections 1b.2 and 2 and the LISA 2.0 User's Manual (Hammond et al., 1992).

- Interpret aerial photography.

    a. Identify landforms.

    b. Determine slope failure modes: shallow (planar/translational) or deep-seated (circular/rotational).

    c. Determine rates of slope movement (slow/rapid).

    d. Determine where failed materials are deposited.

- Create overlays of rock and soil type and mapped structural features at 1:24,000 scale.

- Develop initial model of the processes and rates, and the causes and effects, of slope movement occurring in the analysis area.

- Identify polygons for LISA based on the information gathered above.

- Develop a plan to verify the model in the field.

- Rules of Thumb:

    a. Use one or more sets of early aerial photographs, together with climate models and management history, to gain perspective on process-and-rate, cause-and-effect questions.

    b. The GIS can be an important tool for data analysis and landform identification.

5. Field Exploration (Test Hypothesis)

- See sections 1C.4 and 3.

- Gather information about typical soils, landforms, and ground water characteristics in proposed LISA analysis polygons or areas considered to have a high likelihood of slope failure based on qualitative assessment and professional judgment.

- Confirm/modify landslide inventory information from aerial photography interpretation.

- Measure field-developed cross sections of typical landforms.

- Determine typical soil depths and ground water conditions using a soil auger or drive probe. Locate springs and seeps.

- Sample soil units to verify classification. Use USC field test methods or laboratory analysis.

- Rule of Thumb: Field exploration emphasis is on verifying available published and office information and photo interpretations by visiting representative area. No attempt is made to field-check major portions of the project area at this level of analysis.

6. Analysis

- See sections 1C.4, 2, and LISA 2.0 User's Manual.

- Empirical

  a. Combine office and field information to define areas where landslides have a high, moderate, or low likelihood of occurring under natural and managed conditions.

  b. Ratings are based on knowledge of local geology, soils, and hydrology and on professional judgment.

- Probabilistic or Rational

  Probabilistic (LISA): evaluate the relative landslide hazard of an analysis area from the distribution and variability of soil strength parameters and ground water based on measured or assumed values.

- Rules of Thumb:

  a. Both empirical and rational analysis methods will provide an estimate of landslide. **HAZARD**: The probability of slope failure.

  b. **RISK** is an assessment of the socioeconomic consequences of slope failure.

  c. Responsible land management decision making is based on consideration of both the hazard and risk of slope failure.

7. Report and Recommendations

- See section 1C.4 and the LISA 2.0 User's Manual.

- Summarize the results of investigations and analysis according to standard professional geologic and engineering geologic report formats.

- Rule of Thumb: Integrating analysis results into environmental analysis (NEPA) and planning processes will require close, frequent interaction with everyone on those teams. Written reports are seldom adequate to explain hazard and risk assessment to those unfamiliar with the concepts.

Level II: *Michael Long, Forest Engineering Geologist, Willamette National Forest*

Introduction: A level II analysis is used for project planning; for example, a timber sale with two or three individual units and the transportation system consisting of one to three roads (section 1C.2).

Suggested Checklist :

1. Project Objectives (What are we going to do?)

- Accomplish presale reconnaissance and transportation planning to identify areas of questionable stability either for level III analysis or to avoid them by altering the transportation route and/or harvest plan (section 1C.4).

- Rule of Thumb: Work closely with presale and transportation planners to understand their objectives. Discuss their project constraints to determine how flexible the road locations and sale unit boundaries are (due to budget, multiuse transportation route, and so forth).

2. Initial Literature and Document Review (Past History)

- See sections 1C.4 and 2.

- Obtain 1:24,000 or 1:12,000 aerial photographs.

- Obtain project topographic maps at 1:6000 (1 inch = 500 feet) or 1:3,600 (1 inch = 300 feet) scale.

- Review any previous geotechnical or geologic reports done in the area.

- Review the Forest Soil Resource Inventory (SRI) for pertinent data.

- Review climate and rainfall data.

- Rules of Thumb:

  a. Make at least three copies of topographic maps (one for the field, one for data entry, and one for the report).

b. Take SRI data to the field and verify—share results with watershed group.

3. Field Reconnaissance (What is current condition?)

- See sections 1C.4, 3B.1, 3B.2, 3C, and 3D.
- For transportation routes, this is commonly referred to as a flag or tag line (prior to survey control) or P-line investigation (after survey control has been established).
- For timber sale units, this consists of a reconnaissance of the entire unit on the ground.
- As the route or sale unit is investigated, the area may be divided into sections or cells defined by topography, soil classification, or design criteria.
- Obvious and incipient features of stability concern may be assigned individual distinctive cells.
- Field-developed cross-sections are measured to typify each area.
- Soil and rock units are established and identified. Small samples may be obtained for laboratory analysis for clay content and gradation.
- Rules of Thumb:

  a. Take plastic bags to the field for samples and to protect aerial photographs and maps.

  b. Map transportation routes by "design segments" (full cut, cut and fill, through fill).

  c. Take soil auger, drive probe, and small shovel to obtain samples and to determine soil depth and ground water conditions.

  d. Use geophysics (seismic and resistivity methods) when necessary.

4. Data Synthesis and Initial Hypothesis

- See sections 1C.4, 2, 4E, 5B, and 5C.
- Prepare field-developed cross-sections in stability analysis format shown in plan and section.
- Estimate soil and rock shear strength parameters and ground water conditions.
- Calculate factors of safety according to road design template using SARA (Stability Analysis for Road Access, in process) or timber sale unit areas using DLISA (Deterministic Level I Stability Analysis, 1991).
- Develop level III investigation plan if necessary.
- Rule of Thumb: Use a sensitivity analysis approach to refine shear strength parameters and ground water model.

Level III: *Mark Leverton, Engineering Geologist, Willamette National Forest*

Introduction: A level III analysis is site-specific, measured in hundreds of square feet to a few acres. Mapping is usually generated by the investigator at a scale ranging from 1" = 10' to 1" = 100'.

Suggested Checklist:

1. Project Objectives

- Assess current stability.
- Assess impacts due to management activities.
- Provide range of feasible alternatives and costs.
- Assess risks associated with each alternative.
- Rules of Thumb:

  a. Determine sideboards (cost, management restrictions, etc.).

  b. Stay in contact with pertinent specialists.

  c. Keep intensity of investigation consistent with risk.

2. **Initial Literature and Document Review (Past History)**

- More intensive toward mechanics of failure.
- Local geomorphology.
- Soil and rock shear strength.
- Previous local investigations.
- Rules of Thumb:

  a. Any information is better than none.

  b. Discuss with people acquainted with the area.

  c. Determine and reestablish past survey control points.

3. **Field Reconnaissance (What is current condition?)**

- See section 3C.
- Have field-developed cross-sections been measured?
- Have soil and rock units been established?
- Rules of Thumb:

  a. Establish reproducible survey control.

  b. Take thorough notes understandable to someone else.

  c. End each field day with review of your work and needs.

  d. Photograph pertinent features.

4. **Data Synthesis and Initial Hypothesis**

- First: approximate subsurface interpretation and mechanics of failure.
- Last: develop exploration plan and budget.
- Rules of Thumb:

  a. Do not be afraid of documenting your initial interpretation.

  b. Have multiple hypotheses for subsurface conditions.

  c. Determine what is needed to prove your model.

  d. Determine what needs to be monitored and where.

  e. Complete drawings and interpretation before exploration.

5. **Field Exploration (Test Hypothesis)**

- See section 3D.
- Drive probes/geophysics/backhoe/drill/dye testing/etc., /field material tests.
- Instrumentation/field logging methods.
- Rules of Thumb:

  a. Dress appropriately.

  b. Work safely. This is particularly important at the end of the day.

  c. Anticipate equipment needs and contingencies.

  d. Modify and verify interpretation on drawings serially.

  e. Expect and integrate subsurface "surprises."

  f. Monitor ground water encountered for changes.

  g. Modify exploration plan as needed.

6. **Laboratory Testing**

- See section 4C.

7. Office Data Development

- Take core photographs and complete final logs.
- Develop final subsurface model.
- Rules of Thumb:

  a. Leave a paper trail of observations and assumptions.

  b. Document what is known AND what is unknown.

8. Analysis/Develop Alternatives

- XSTABL (1992)
- GW (Prellwitz, 1990)
- DLISA (1991)
- Document analysis assumptions.
- Rules of Thumb:

  a. Handwritten notes on computer printouts are good.

  b. Are assumptions consistent with field observations?

9. Report/Recommendations

- Clear, thorough, brief report (see first rule of thumb below).
- Present the full range of feasible alternatives.
- Present risk assessment and cost/ benefit analysis.
- Rules of Thumb:

  a. Consider writing a thorough report for your files with procedure, assumptions, knowns, unknowns, classifications, analysis, etc., and a brief clear memo (one or two pages) documenting results, alternatives, costs, risks, and recommendation for your client.

  b. Test the documentation process as though someone else will be continuing the work you started. Be thorough.

10. Construction

- See section 6.
- Rules of Thumb:

  a. If you designed it, be there when it is built.

  b. Verify assumptions during excavation.

  c. Modify interpretive drawings if necessary.

11. Post-Construction Monitoring

- See section 6K
- Rules of Thumb:

  a. The monitoring system should be functional for several years.

  b. Ensure reproducible survey control.

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